



**CONTEMPORARY
SCIENCE EDUCATION
RESEARCH:
INTERNATIONAL
PERSPECTIVES**

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EDITORS

M. F. TAŞAR & G. ÇAKMAKCI

CONTEMPORARY SCIENCE EDUCATION RESEARCH:
INTERNATIONAL PERSPECTIVES

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TABLE OF CONTENTS

Preface	xiii
PART 1: The Nature of Scientific Content	
Students' pre- and post-teaching analogical reasoning <i>Rosária Justi</i> <i>Nilmara Braga Mozzaer</i>	3-12
Similarities about digestion elaborated by children <i>Mariana Cunha</i> <i>Rosária Justi</i>	13-19
Visualization and modeling in the learning of science <i>Convenor: Professor John K. Gilbert</i> <i>Discussant: Professor M. Gail Jones</i>	21-22
Visualization in learning about chemical equilibrium <i>İlkay B. Ataç Özdemir</i> <i>Dilek Ardaç</i>	23-32
A web-based learning tool that emphasises the role of visuals in supporting argumentative claims <i>Neslihan Er</i> <i>Dilek Ardaç</i>	33-42
The use of a model of modelling to develop visualization during the learning of ionic bonding <i>John K. Gilbert</i> <i>Rosária Justi</i> <i>Ariadne S. Queiroz</i>	43-51
Case studies of students' visualization of science – a dual coding perspective <i>Maurice Cheng</i> <i>John K. Gilbert</i>	53-63
Recognizing the structural role of mathematics in physical thought <i>Ricardo Karam</i> <i>Maurício Pietrocola</i>	65-76
Generating scientific knowledge in optics via phenomenology <i>Wilfried Sommer</i> <i>Johannes Grebe-Ellis</i>	77-83
Argumentation about and understanding of science: research exploring how to interrelate these two different perspectives <i>Claudia von Aufschnaiter</i>	85-86
Argumentation & scientific conceptions in peer discussions: a comparison between Catalan & English students <i>Marina Castells</i> <i>Sibel Erduran</i> <i>Aikaterini Konstantinidou</i>	87-97

Argumentation and scientific reasoning: the “double hierarchy” argument <i>Aikaterini Konstantinidou</i> <i>Josep M^a Cervero</i> <i>Marina Castells</i>	99-108
The quality of students’ argumentation and their conceptual understanding – an exploration of their interrelationship <i>Tanja Riemeier</i> <i>Jan Fleischbauer</i> <i>Christian Rogge</i> <i>Claudia von Aufschnaiter</i>	109-114
Methods for investigating students’ learning and interaction with a haptic virtual biomolecular model <i>Gunnar E. Höst</i> <i>Konrad J. Schönborn</i> <i>Petter Bivall Persson</i> <i>Lena A. E. Tibell</i>	115-121
Model of cognitive architecture of common and scientific concepts <i>Paul Tarábek</i>	123-133
The discipline - culture model and conceptual analysis in science education: the case of teaching quantum field theory <i>Eugenio Bertozzi</i> <i>Igal Galili</i> <i>Olivia Levrini</i>	135-144
How do pre-service secondary science teachers strategize their pedagogy to teach for conceptual change <i>Deb McGregor & Peter Taylor</i>	145-153
Guiding the physics students to the doorsteps of modeling through the gateways of assumptions and analogies <i>Bhupati Chakrabarti</i>	155-160
The organization of chemistry as conceived by undergraduate students – a study using concept maps <i>Paulo Alves Porto</i> <i>Paola Corio</i> <i>Flavio Antonio Maximiano</i> <i>Carmen Fernandez</i>	161-166
Does the Term Dynamometer Reflect Its Linguistic Meaning? What Should Be Called: Forcemeter, Wattmeter, Joulemeter...? Why? <i>Eugenio Fernández Durán</i> <i>Enrique Jiménez Gómez</i> <i>Isabel Solano Martínez</i>	167-171
University students’ epistemological beliefs on natural and social sciences <i>Flavia Rezende</i> <i>Isabella Oliveira</i>	173-177

Which Definition(s) of Weight Do We Teach? Which One Is Correct? <i>Ulaş Üstün</i> <i>Ali Eryılmaz</i>	179-184
What is the North Star of Teachers? Curriculum or National Exams <i>Cezmi Ünal</i> <i>Haki Peşman</i> <i>Ömer Faruk Özdemir</i>	185-187
Chemical representations: bridging submicroscopic and symbolic dimensions of chemical knowledge in light of Peirce's theory of sign <i>Jackson Gois</i> <i>Marcelo Giordan</i>	189-192

PART 2: History, Philosophy, and Sociology of Science

Biology professors' and teachers' positions regarding biological evolution and evolution education in a middle eastern society <i>Saouma, BouJaoude</i> <i>Anila Asghar</i> <i>Jason Wiles</i> <i>Lama Jaber</i> <i>Dian Sarriddine</i> <i>Brian Alters</i>	195-206
Epistemological beliefs in science: an exploratory study of Lebanese university students' epistemologies <i>Lama Jaber</i> <i>Sarah Halwany</i> <i>Nadya Rizk</i> <i>Saouma BouJaoude</i>	207-216
An analysis of status and obstacles of implementation of history and philosophy of science in science education <i>Dietmar Höttecke</i>	217-226
Development of a valid and reliable protocol for the assessment of early childhood students' conceptions of nature of science and scientific inquiry <i>Judith S. Lederman</i> <i>Norman G. Lederman</i>	227-236
Are historical contexts suitable for assessing students' competences in the field of nature of science and scientific inquiry? <i>Irene Zilker</i> <i>Gary M. Holliday</i> <i>Hans E. Fischer</i> <i>Alexander Kauertz</i> <i>Judith S. Lederman</i> <i>Norman G. Lederman</i>	237-244

Exploring competencies in understanding the nature of science and scientific inquiry <i>Kerstin Kremer</i> <i>Christiane Grube</i> <i>Detlef Urbahne</i> <i>Jürgen Mayer</i>	245-254
The role of epistemological beliefs in high school students' learning strategy <i>Cansel Kadioglu</i> <i>Esen Uzuntiryaki</i> <i>Yesim Capa Aydin</i>	255-260
Relationship between Hong Kong students' understanding of the nature of science and their attitude towards science <i>Wing Man Chan</i> <i>Siu Ling Wong</i>	261-267
Nature of science versus nature of engineering: first-year engineering students' views of science and engineering relations <i>Faik O. Karatas</i> <i>George M. Bodner</i> <i>Muammer Calik</i>	269-275
Elementary school students' perceptions about scientists <i>Zeynep Erkorkmaz</i> <i>Dilek Erduran Avcı</i> <i>M. Zeki Yıldırım</i>	277-283
A study of student beliefs about the epistemology of science and their relationship with students' personal epistemologies <i>Andri Christodoulou</i> <i>Jonathan Osborne</i> <i>Katherine Richardson</i> <i>Christina Howell-Richardson</i> <i>Shirley Simon</i>	285-295
Discipline-culture framework of implementing the history and philosophy of science into science teaching <i>Igal Galili</i>	297-307
An assessment into pre-service biology teachers' approaches to the theory of evolution and the nature of science <i>Çiçek Dilek Bakanay</i> <i>Serhat İrez</i>	309-318
The effect of the science camp program on children's views of the tentative nature of science <i>Duygu Metin</i> <i>Gulsen Bağcı Kılıç</i>	319-329
Evaluating the learning potency of historical and epistemological relevant dialogues <i>Helmut F. Mikkelsen</i>	331-339

PART 3: Informal – Outdoor Science Education

Effect of nature-based education on a camp on children's attitudes toward environment and their ideas about human-nature interaction <i>Esra Yardimci</i> <i>Gulsen Bagci Kilic</i>	343-351
Connecting formal and non-formal astronomical learning: an integrated educational program using an inflatable planetarium permanently located in a school <i>Dimitra Lelinguou</i> <i>Katerina Plakitsi</i>	353-358
Atom surprise: using science drama to teach basic science <i>Ran Peleg</i> <i>Ayelet Baram-Tsabari</i>	369-367
Analyzing interaction of different contexts in a science centre: the case of solar astronomy courses <i>Silvia Calbo Aroca</i> <i>Cibelle Celestino Silva</i>	369-377
Implementation of physics education in nature: framing informal instruction into formal setting <i>Zeynep Gürel</i> <i>Yasemin Doğan</i>	379-386
The motivational features of an industry site visit <i>Anni Loukomies</i> <i>Jari Lavonen</i> <i>Kalle Juuti</i>	387-394
A pilot nature education in national parks program: the case of Küre and Ilgaz mountain national parks <i>Ela Ayse Köksal</i> <i>Mehmet Erdoğan</i> <i>Murat Aydemir</i> <i>Fulya Öner Armağan</i>	395-404
Examining formal, informal-outdoor science experiences, and interest in science among Turkish pre-service elementary science teachers <i>Mizrap Bulunuz</i>	405-407
Patterns of teachers' thinking on school visits to a science museum <i>Maitte Morentin</i> <i>Jenaro Guisasola</i>	409-411

PART 4: Science Curriculum and Evaluation

The relationship between teachers' beliefs and their practice: how the literature can inform science education reformers and researchers <i>Khalid Bingimlas</i> <i>Mary Hanrahan</i>	415-422
Greek trends in cross-thematic-integration of curriculum as in unified teaching of natural sciences <i>Ismeni Ioannidou</i> <i>Vassilis Banos</i>	423-427
Teaching science in the Irish transition year: a wasted opportunity <i>Peter E. Childs</i> <i>Sarah Hayes</i> <i>Lorraine Lally</i>	429-438
Tensions that students face in the lego-engineering, design-based simple machines module <i>Ismail Marulcu</i> <i>Michael Barnett</i>	439-445
Creationist conceptions of primary and secondary school teachers in nineteen countries <i>Pierre Clément</i> <i>Marie Pierre Quessada</i> <i>François Munoz</i> <i>Charline Laurent</i> <i>Adriana Valente</i> <i>Graça S. Carvalho</i>	447-452
Effects of task profiles on students performance in PISA 2003 <i>Holger Stanitz</i> <i>Stefan Rumann</i> <i>Jens Fleischer</i> <i>Joachim Wirth</i>	453-457
The genetic determinism of human performances: a comparison between teachers' conceptions in Finland and France <i>Jérémy Castéra</i> <i>Pierre Clément</i>	459-466
Science curriculum change in England: how science works for pre-service teachers <i>Charles Golabek</i> <i>Rob Toplis</i> <i>Anna Cleaves</i>	467-472
The effect of design of reproduction and growth of living species unit in primary school eighth grade science course curriculum on the acquisition of behaviors aimed <i>Dilek Zeren Özer</i> <i>Mublis Özkan</i>	473-476
The comparison of the representation of science process skills in 9th grade chemistry curricula: Germany, France, Canada and Turkey <i>Abdullah Aydın</i>	477-482

Analysing the support for and obstacles to integrating education for sustainable development in France

483-489

Jean-Marc Lange
Laurence Simonneaux
Alain Legardez
Yves Girault

Preface

This book is composed of 4 parts: **Part 1: The Nature of Scientific Content; Part 2: History, Philosophy, and Sociology of Science; Part 3: Informal – Outdoor Science Education; and Part 4: Science Curriculum and Evaluation.** In these four parts there are 24, 15, 9, and 11 papers respectively. Altogether this collection of papers truly reflects the international perspectives on these four selected topics. The reader will easily recognize the leading scholars of the field as well. We are sure that the reader will find the articles provocative and inspiring. By looking at these articles we can find ways of improving and even suggestions for our colleagues. Thus, this book is not an end in itself but a means of further debate in the field.

We wish to thank all of the contributors in this book for their hard work.

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PART 1
THE NATURE OF SCIENTIFIC CONTENT

STUDENTS' PRE- AND POST-TEACHING ANALOGICAL REASONING

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Abstract

In this study, we investigate students' analogical reasoning as a creative process in which they were stimulated to generate and explain their own analogies. All the data has been gathered from pre- and post-teaching interviews, in which the students had been asked to establish comparisons which could explain how atoms get bound. Such data supported the discussion about how students reasoned analogically. Moreover, they had made it evident that the task aims and the students' salient knowledge have exerted great influence on the elaboration of the analogies.

Background and Justification

Analogies – models that establish relationships between two domains – are parts of human being thinking. Through them, we can acquire new knowledge or change those that already exist in our cognitive structure. In this sense, understanding how the analogical reasoning process occurs becomes an essential condition for understanding how we learn.

In this paper, we assume analogies as models that favour the establishment of relationships between a familiar domain and an unknown one, called *base* (Gentner, 1989) or *analog* (Glynn, 1991) and *target* (Gentner, 1989; Glynn, 1991), respectively. It is the existence of an analogical relationship between different domains which represent an idea that makes an analogy be a model (Duit, 1991). We also consider two other types of comparisons: *literal similarities* and *mere appearance*. According to Gentner (Gentner, 1989; Gentner & Holyoak, 1997), literal similarities, like analogies, are comparisons in which relational predicates are mapped. Moreover, in literal similarities, object attributes are also mapped. On the other hand, in mere appearance matches, only object attributes are mapped between the two domains.

Despite its importance, there is no general agreement in cognitive science literature (for instance, Gentner, 1989; Holyoak & Thagard, 1997; Vosniadou, 1989; Wilbers & Duit, 2006) about how the analogical reasoning process occurs. In attempting to understand analogical reasoning, this process has been decomposed into basic sub-processes: (i) access: one or more relevant known domains should be accessed; (ii) mapping: one familiar domain is mapped to the target domain by identifying systematic correspondences between them; (iii) evaluation of the match; (iv) proposition of inferences in the target, producing new knowledge and favouring domain understanding; and, sometimes (v) generalization: extension of inferences to all cases in which they could be applied.

Most of the current analogical reasoning views – like the Gentner's structure-mapping (Gentner, 1989; Gentner & Holyoak, 1997), Holyoak and Thargard's multiconstraint theory (Holyoak & Thagard, 1997), the analogical mechanism described by Vosniadou (1989), and the heuristic analogy mechanism (Wilbers & Duit, 2006) – deal with such sub-processes. The differences among all those views are in the emphases and particular

restrictions concerning with explanations proposed by each of them. However, most of them present a common problem, emphasised by Abrantes (1999):

“The real problem for a theory of analogy would be to give an account of the construction of representations and the mapping as intertwined processes. In this view, a theory of analogy cannot be based purely on syntactical constraints” (Abrantes, 1999, p. 244).

This points out the need of investigating deeply how each of the sub-processes occurs, as well as which factors influence on each other.

In order to learn science, many times students have to understand abstract concepts. Assuming the potential of establishing relationships between such concepts and others that are already familiar to students, analogies can play an important role as learning tools. On account of this, teachers and textbooks present analogies that, when interpreted by students in the intended way, contribute to a better understanding of the theme being studied.

Furthermore, assuming the teaching constructivist perspective – according to which learning occurs when students establish relationships between what they already know and the new knowledge – it emerges the relevance of involving students in elaborating their own analogies rather than in only trying to understand those that are presented to them. However, to adequately use such a situation in teaching, it is crucial to understand the analogical reasoning process.

Few studies have been conducted on analogical reasoning in which students generate, spontaneously use, and modify their own analogies (Cosgrove, 1995; Kaufman, Patel, & Madger, 1996; Pittman, 1999; Wong, 1993). Taking into account the gaps in the literature about analogical reasoning, and in accordance with research about subjects’ generation of their own analogies, we believe that one of the possible ways to access the representations of who generates an analogy is not delimiting the access sub-process.

Purpose

In the current paper, that is part of a broad study (Mozzer, 2008), our general idea is to allow subjects to generate their own analogies about a given domain and to try to understand comprehensively how they reason analogically (with special attention to the influence of their general knowledge on specific analogical reasoning sub-process).

Assuming the importance of analogies in supporting the understanding of abstract themes, we have chosen the theme chemical bonding as the analogies target domain. Thus, the study is mainly focused on the following research question: how do students elaborate analogies about chemical bonding before and after they had been taught about this theme?

Methodology

After the approval of the Research Ethical Committee of the Federal University of Minas Gerais (in Brazil), and the signing of consent forms by students and their parents, data were collected from clinical interviews conducted with sixteen 13-14 year-old students. This sample was selected among one of the researchers’ students due to issues that contributed to conduct the investigation: the researcher herself could control the content that was being taught and how the teaching was occurring (something important for probing possible influences from teaching into students’ comparisons); the existence of an excellent personal relationship between the teacher-researcher and the students (something important for establishing the necessary rapport between students and the interviewer); and the facility of meeting the students in both the school environment and adequate scheduling times.

The interviews were open and semi-structured. We opted for this kind of interview because it is based on a systematic intervention from the interviewer in the face of the interviewee's behaviour in order to make it clear the meaning of their actions, explanations (or both) at different moments of the interview – something that we judged as essential in our attempt to understand students' reasoning.

The main theme of the interviews was chemical bonding. This theme was chosen because it is an abstract one, therefore considering to favour the use of analogies (Coll, 2006; Thagard, 1992). They were conducted in two moments: before and after the chemical bonding teaching. This was so because we aimed at investigating the influence of students' knowledge on their analogical reasoning. They were conducted by the second author – who was also the students' chemistry teacher –, and were video-recorded. In both interviews, the same set of basic questions was asked in order to assure the reliability of data collection. However, the questions order and the level of depth that each of them was discussed varied according to each student' answers.

The pre-teaching interviews were conducted when students had been studying about atomic models (basically the main attributes of the models proposed by Dalton, Thomson, Rutherford and Bohr). Initially, the interviewer informed about the interview general aims, and the importance of students trying to express their own ideas in the most possible detailed way. Then the interviewer tried to check whether students had any idea about chemical bonding by asking them about both the water molecule formula, and the origin of its formation. In so doing, we aimed at verifying whether students had already thought about the establishment of bonding between atoms. Next, depending on the answers, the interviewer probed their ideas about how they imagined the occurrence of such bonding. When a given student said nothing about the atoms being bound, the interviewer asserted that the hydrogen and oxygen atoms stuck together in the water molecule, and asked students to explain how they understood such an assertion.

In order to favour the expression of students' ideas, the interviewer made some materials available for them (polystyrene balls of different sizes and colours, sticks, paper, colour pencils, coloured play-dough). However, such materials were previously in a box. They were only presented to students when they had already expressed some ideas verbally. We opted for that in order neither to limit their representations nor to induce them to use a given mode of representation just because they had seen a specific material.

After students had expressed their initial ideas about the atoms binding, and in order to help students in understanding the following question, the interviewer asked them whether they understood the meaning of a comparison, and mentioned the functional analogy between our fingers and tongs. Then, she asked them to explain their ideas about atoms bonding by using a comparison. From that moment on, the interviewer always asked the students to generate comparisons to express their ideas. Moreover, she asked them to make all the mappings explicit, and justify all their options and ideas.

The post-teaching interviews occurred after the initial classes about chemical bonding. Such classes were mainly focused on the energetic issues related to the stability of bonding atoms.

In the second interview, students could watch parts of the first interview video, and comment their previous answers. Through this trustworthiness process – called members checking (Brenner, 2006) – we aimed at comparing our interpretations to students' ideas and models presented in the first interview with their own views about such ideas and models. From the students' comments about their initial ideas and comparisons, the interviewer asked other questions in order to help them to either detail or better justify their current ideas. Particularly, questions regarding students' comparisons also aimed at probing whether they were able to both recognise the existence of limitations and modify their comparisons.

The interview videos were transcribed verbatim from two perspectives: (i) detailed transcriptions of verbal and non-verbal behaviours from both students and interviewer – *molecular analysis* (Erickson, 2006); (ii) selection of

parts of the interviews in which the main ideas to be investigated were expressed – *molar analysis* (Erickson, 2006). Then, the data were described in case studies for each student.

In the case studies, we present the relational comparisons (analogies and literal similarities) as diagrams. We also discuss: the students' explicit ideas (like content knowledge or about their comparisons); students' implicit ideas (like some alternative conceptions that were not explicit, but clearly fostered some of their ideas); the students' non verbal behaviour (like the way they used the available materials and their gestures); the characteristics of their comparisons; and their judgements about their own comparisons.

Results and Analysis

In this current paper, due to space limitation, we present, as an example, the most significant parts of one student's case study. This specific case study was selected because it is representative of the analogical reasoning we analyse for all students. Obviously, there are some inherent particularities in the reasoning process, which are also discussed. In accordance with research ethical principles, the name of the student – Paul – is a fictitious one.

Paul's initial interview was conducted immediately before the Bohr atomic model teaching. When questioned about how he imagined the atom, Paul asserted that it would be like a ball full of electrons moving in circles inside it, and that the atom nucleus would also be inside that ball.

In his representation for the water molecule, Paul took hold of a big and green polystyrene ball – that he identified as representing the oxygen atom – and, with the help of two sticks, he attached two smaller orange polystyrene balls – identified as representing the hydrogen atoms (Figure 1).

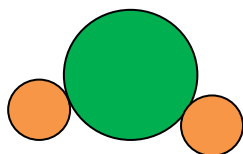


Figure 1. Paul's representation for the particles that compose the water molecule generated during the first interview.

For him, the origin of the atoms union would be the fact that, due to their movement, they would approach each other and their nucleus would stick together, forming a unique nucleus. The atoms that had lost their nuclei (orange balls) would become negative and the atom which had gotten the binding nucleus (green ball) would become positive. Therefore, they would attract each other.

Although Paul had established a comparison between the atom and a ball, he mapped only descriptive properties, as emphasised in Diagram 1¹. In other words, he established a mere appearance comparison (Gentner, 1989; Gentner & Holyoak, 1997).

BASE		TARGET
Ball	←————→	atom
hollow	←-----→	hollow
limiting surface	←-----→	limiting surface

Diagram 1. Paul's mapping for the comparison between the atom and a ball.

¹ In this, as well as in all the other diagrams, correspondences between objects are represented by thin double arrows; combinations of attributes are represented by dotted double arrows, and relational combinations are represented by thick double arrows.

One of the most interesting comparisons drawn by the student was expressed when he tried to explain the union between the atoms which constitute the water molecule:

It would be like the family ties between a mother and her child. They are united to each other, not physically, but from feelings... Here it is the same thing. It is as if this ball (pointing to the green ball he had used to represent an oxygen atom) were the mother and this one (the orange one, that represented a hydrogen atom) were the children. They would be attracted by feelings.

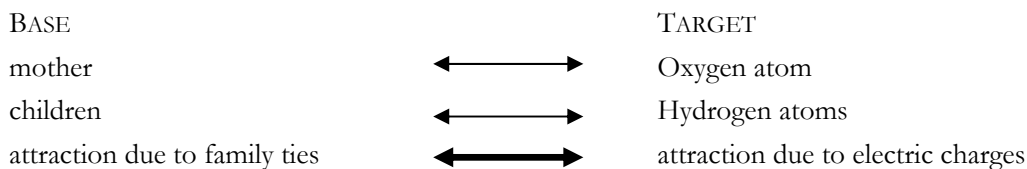


Diagram 2. Paul's mapping for the analogy between mother, children, and atoms.

When discussing his comparison, although attributes like the atoms size and the size of mother and children seemed to be implicit in his representations, they were not explicitly mapped, which made us think that they were ignored in the process. On the other hand, the relational mapping between the electrostatic attraction between the atoms and the emotional attraction between the mother and her child was expressed in a clear way. By so doing, he provided us with evidence of his understanding about the electric nature of matter, which supported our classification of his comparison as an analogy. Assuming that up to the period of that interview, the student had already learnt about atomic models, this analog shows a great influence of his previous knowledge on those compared domains.

However, the fact that he has been able to establish a relational comparison does not mean that he had represented the target domain in the way a science teacher would expect him to. We could confirm this from the explanations he gave about his representation:

One is very near the other (referring to the atoms), as if they were a magnet and a piece of metal... Then, when you put them closer to each other, the magnet grasps the metal, or the metal grasps the magnet (I don't know which one).

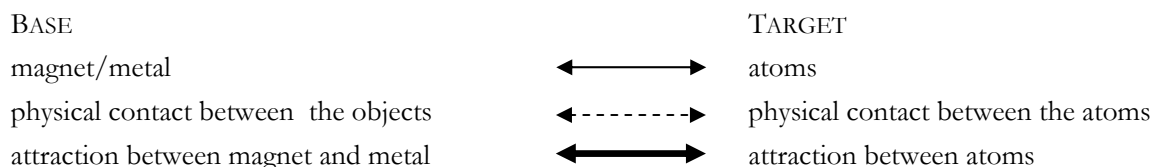


Diagram 3. Paul's mapping for the literal similarity between magnet/metal and atoms.

In this comparison, Paul established a relationship between the attraction between magnets and pieces of metals and the attraction between different atoms. Moreover, although in the previous analogy he had emphasised that the attraction between mother and children would not result in physical contact between them, here he showed that he imagined the atoms would be in physical contact when bound to each other. This was made evident by both his description of the atom (as a hollow ball with a material limiting surface) and his comments about this idea during the second interview. Therefore, we understand that, in this new comparison, he also combined base and target attributes, which made it a literal similarity.

When asked to compare the attraction between the atoms, he proposed an analogy involving the gravitational attraction between the sun and the planets and the attraction between the atoms, as emphasised in Diagram 4:

The sun and the orbit... the earth. The planets and the sun. (...) But closer to each other... much more attracted.

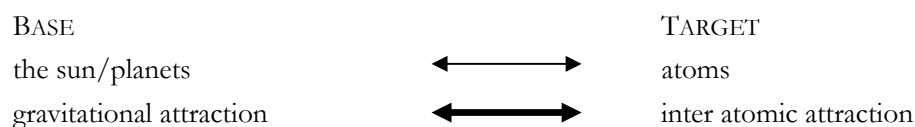


Diagram 4. Paul's mapping for the analogy between the solar system and the atoms.

In this analogy², as in the previous one, Paul combined relational predicates and ignored object attributes. He confirmed that, when comparing the relationship between mother and children to the atoms, he had thought in a similar way he did when he thought to generate this analogy.

The second interview was conducted after all the classes about introduction to chemical bonding. In such classes, initially the teacher discussed the fact that substances were composed of atoms and that their types and/or combinations are different to different substances. After that, the students observed the burning of a piece of magnesium. This phenomenon supported the discussions which aimed at proposing explanations for: (i) why atoms bind to each other; (ii) why there are substances comprised of isolated atoms; (iii) why atoms, after been bound to each other, continue to stick together.

When Paul's second interview occurred, he had just studied covalent bonding. At that time, he expressed the same ideas for the constitution of the water molecule: two hydrogen atoms and one oxygen atom. However, his ideas about how atoms are bound to each other had changed, as shown by his explanations:

One atom is attracting the other one, the nucleus from one atom is attracting the electrons from the other atom... The nucleus from one atom attracts the electrons from the other, and there is also a repulsion force between the two nuclei. But they are very close to each other.

When asked to explain the meaning of "very close", Paul said that, differently from the first interview, when he had thought "union" as synonymous with atoms being side by side, at that moment he thought this meant the attraction force between the nucleus from one atom and the electrons from the other one.

After watching parts of his first interview video, the interviewer invited him to discuss some of his previous ideas in the light of his current ideas. Then, he expressed the idea presented above, and asserted that, according to the Dalton's atomic model, his previous ideas would be correct. On the other hand, according to the Bohr's atomic model, they would be wrong, because he had ignored the repulsion force between the nuclei. He also commented that he thought the idea of union and migration of nucleus from one atom to another was wrong because the nuclei would remain in their original atoms, and only an attraction between them would exist.

Although during the first interview Paul had established a comparison between the inter atomic attraction and the sun-planets attraction, he had not explained whether he thought on same nature forces, i.e., whether he imagined that the forces exerted by the sun on the planets had the same electrical nature as the force exerted between atoms. As this directly influenced the type of comparison he had generated in the first interview, the interviewer asked him to explain better his original ideas. He explained that, whilst the attraction between the sun and the planets would occur due to the gravity force, the attraction between the nuclei would occur due to the positive and negative charges. However, he thought of them as similar forces in the sense of subjacent reciprocity:

In this way: both would be attracted. The sun attracts the planet and the planet attracts the sun. And the nucleus attracts the electrons as the electrons attract the nucleus.

This explanation was very important in order to confirm our belief that Paul had generated an analogy when comparing such domains in the first interview.

² We assume as analogies generated by students the comparisons which relations were realised by them, even when they were not able to name them by using the scientific nomenclature or when they were not able to identify their origins.

Following, Paul was invited to make a comparison that could explain the union between atoms. He stated:

I was thinking about the previous comparison between the mother and her child, but in the case in which the child were an adolescent. There are two attractions: from the child to the mother and from the mother to the child. Both of them are very strong but... if you were an adolescent, you would not like to arrive at a party with your mother. Your mother takes you to the party by car, but you don't want her to stay around. You don't want her to keep on holding you all the time.

BASE		TARGET
mother/adolescent child	←→	atoms
attraction due to family ties	←→	attraction due to opposite electric charged particles
repulsion due to embarrassment	←→	repulsion due to same electric charged particles

Diagram 5. Paul's mapping for the analogy between mother/adolescent and atoms.

As emphasised in diagram 5, when drawing this analogy, the student mapped not only the relationship between the attraction due to family ties and the attraction due to the opposite signal charges, but also the repulsion of adolescents concerning their mothers due to their embarrassment caused by the mother's presence and the repulsion that exists between same signal charges. He was also able to apply the ideas of attraction and repulsion when explaining how water molecules are comprised of hydrogen and oxygen atoms. He represented the water molecule as in figure 2, and explained that the central atom was the oxygen one, and that the other two atoms were the hydrogen ones, repeating his given explanation for the origin of the attractive and repulsive forces, and emphasising that they should be balanced.

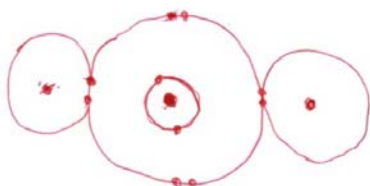


Figure 2. Paul's representation for the particles that compose the water molecule generated during the second interview.

It seems that such knowledge supported the analogy generated by the student in the second interview, which made it evident the importance of the knowledge available to the individual when he generates his/her analogies.

Conclusions and Implications

From the results and analyses presented here, we conclude about how Paul generated analogies in the context of this study by emphasising issues that we view as determining to such a process.

In accessing the base domains, Paul was guided by the aim of solving a given problem situation (to explain the union between the atoms), as emphasised by Holyoak and Thargard (1997) and Gentner (Gentner, 1989; Gentner & Holyoak, 1997). This can be confirmed, for instance, by the fact that he selected the magnet as a base domain, probably because it presents an attractive behaviour similar to the one he aimed at explaining.

Although most of the entities of the base domain selected by him were concrete ones (sun, planets, people), he also mapped abstract functional relationships (attractive and repulsive forces). When mapping these relationships, he ignored the descriptive properties of objects, or object attributes (size, colour). This corroborates the ideas of *structural alignment* and the *systematicity principle* proposed by Gentner (Gentner, 1989; Gentner & Holyoak, 1997) in her structure-mapping theory. In her view, the compared objects are put in correspondence to each other according to the role they play in the common relational structure. From this, it implies that the analogical reasoning is independent of the conceptual domain which the compared domains belong to, i.e., it does not matter whether they

originated from equal or different conceptual domains (Vosniadou, 1989). This aspect was also corroborated by our data concerning Paul's analogical reasoning because he generated analogies between domains inside the scientific context (like magnets and atoms), as well as between domains outside the scientific context (like people and atoms).

The accessing sub-process in this student's analogical reasoning was influenced not only by the aims of the task, but also by formal information sources (teacher, textbooks, classes) and informal ones (daily experience). The two of them comprise what we call *student's salient knowledge*: part of the knowledge available in his cognitive structure, originating from his daily and scholar knowledge and from which the named salient similarities³ (Vosniadou, 1989) are derived.

In our view, this would be responsible for students perceiving and mapping specific similarities between compared domains among several possible ones. Moreover, our data showed that both – aims and salient knowledge – also exert straight influence on the mapping sub-process, determining the kind of comparison drawn by the students, as well as the number of mapping relationships. The first influence was evidenced by the fact that Paul had identified and selected functional relations, guided by the aim to explain processes that involved entities from the target domain rather than explain the entities themselves. The second influence was evidenced, for instance, when Paul, in the initial interview, showed superficial ideas concerning a target domain, thus resulting in the generation of a mere appearance comparison, i.e., without any relational mapping. On the contrary, in the second interview, by showing a salient knowledge well based on specific aspects from scientific knowledge (for instance, the existence of a balance between electrostatic forces in bonding atoms), he was able to map more than one relation between the compared domains (affective attraction to electrostatic attraction and affective repulsion to electrostatic repulsion).

Duit and Wilbers proposed an analogical reasoning model from studies conducted with physics students for whom the base and target domains were selected, images about the base domain were given, and mapping between the two domains were asked for (Duit, Roth, Komorek, & Wilbers, 1998; Wilbers & Duit, 2006). The authors assert that students, when confronted with the base domains, generate mental images and intuitive schemes from which they establish preliminary associations between the compared domains. In our context, students were asked to generate their own analogies. Therefore, we assert that the associations mentioned by Duit and Wilbers can be restricted neither to mental images nor to intuitive schemes. Rather, they can be related to a broad system of salient knowledge in the students' cognitive structure. In our view, such knowledge would be responsible for the fact that students realise and map specific similarities among those possible ones between the compared domains.

The inferences and evaluations in Paul's analogical reasoning were favoured by encouragement provided by the interviewer when she asked for deeper explanations concerning his analogies. When explaining his analogies – for instance, when the interviewer asked him about the meaning of “very close”, an expression he had previously mentioned – they were changed. In our view, this happens because, when students provide explanations, they can do it without thinking about what they say, just trying to satisfy who is questioning them. However, when they are asked to better explain something that, sometimes, is not clear even for them or seems incoherent with their other ideas, students are motivated to really reflect on them, which may result in changing or substituting them.

Paul tended to identify limitations in his analogies only when he was asked to discuss his comparisons generated in the first interview in the light of his knowledge during the second interview. Such a process, as we could expect, was also influenced by his salient knowledge.

³ According to Vosniadou, salient similarity is a “similarity grounded in easily retrievable aspects of representations, regardless of whether or not they represent descriptive or relational, perceptual or conceptual properties” (Vosniadou & Ortony, 1989, p. 4). Therefore, “what matters is only the status that such that these properties have with respect to people's underlying representations” (Vosniadou, 1989, p. 420).

All the aspects that support the sub-processes, except the identification of limitations (that was asked for only in the second interview), were observed when students generated analogies in both interview phases: pre- and post-teaching. From a comparison between both interviews, we also observed a change in the depth level of the similarities mapped by students, since the focus of the relations mapped by students changed from the electric nature of matter to the simultaneity of attractive and repulsive forces, after the classes that introduced the theme chemical bonding. We view that fact as another evidence that the students' salient knowledge influence their analogical reasoning. In general, our data corroborates Vosniadou's (1989) idea that the individual's analogical mechanism develops according to his/her conceptual development rather than through a developmental change, as proposed by Gentner (1989), since students were able to generate relational comparisons which can be differentiated by the abstraction level that based their ideas.

In this study context, we have not observed the sub-process of generalisation in Paul's (or any of the other students) analogical reasoning.

In the most frequent use of analogies in science teaching, the domains to be compared are given by the teacher aiming at students' identification of proper mapping. From what we discussed here, we can assert that students can interpret domains in a different manner from that one expected because they ignore scientific concepts and principles that the teacher assumes to be part of their knowledge. From our data, and assuming a context in which students are asked to generate their own analogies (including, perhaps mainly, the selection of the base domain), such analogies are generated from the available salient knowledge at that student cognitive structure when s/he reasons analogically.

At the same time, our data also made it evident that, even if the salient knowledge were not well-formed, it could contribute to a better understanding of the compared domains (Wong, 1993), providing the basis for the building of deep relationships based on scientific knowledge. According to Dagher (1995), such change can be useful not due to the following conceptual change itself, but due to the evolution process from previous ideas to scientific acceptable conceptions.

This process, during which new knowledge can be built, can occur under teachers' supervision (Dagher, 1995). As demonstrated by Gick and Holyoak (1983) from a series of studies on problem solving, the main improvement in students' performance occurred when they were guided about the way to use the base domain. Moreover, one of our conclusion important implications is the fact that, when providing conditions in which students can elaborate their own analogies, the teacher can get information about students' salient knowledge on the theme to be taught, as well as about *the way* students understand the new concepts which are taught. This can be an adequate basis for teachers' future action plans. Thus, the promotion of teaching activities that allow students to generate, express, and analyse their own analogies is a promising alternative because, as any other scientific reasoning skill, the analogical reasoning can be developed and, maybe, explicitly taught (Kaufman et al., 1996).

As Duit (1991) emphasised, the aim of using analogies in science teaching must go beyond a didactic aim. Analogies can be used as tools that give students the opportunities to make predictions, and, mainly, to experience a model building process from which s/he could learn reasoning skills and scientific attitudes – issues which, for us, are as important as the learning of the desired curricular model.

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SIMILARITIES ABOUT DIGESTION ELABORATED BY CHILDREN

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Abstract

In this paper, we analyse comparisons proposed by 9-11 years-old children when they were asked about digestion. The main aim is to discuss the similarities (analogies and mere-appearance matches) they elaborated. Each child was interviewed twice. Data showed that the children elaborated both kinds of similarities. The mere-appearance similarities were mainly elaborated during the first interview and were related to organs shapes, whilst the analogies were mainly focused on the role of some organs and on some parts of the digestion process. Our analysis showed that (i) the base domain selection can be hard, even when a familiar domain is known; (ii) children's performances in activities that require analogies elaboration are influenced by their creativity and imagination. These and other conclusions support our claim that the use of activities that require children's elaboration of analogies must be part of teachers' education.

Background, Framework, and Purpose

Children's ideas about the theme

The human body subject had already been discussed in many studies about students' conceptions from different ages and school levels. According to Carraher (1987), children have difficult to relate food ingested and the faeces eliminated. Moreover, they do not succeed in explaining how nutrients founded in food can make them grow up. Some of them tell that the food putrefies, others that it mixes with some substances inside the body to produce faeces.

The study conducted by Cakici (2005) about primary level students' understanding on digestion showed that, even after they had been thought about the theme, students proposed non-scientific explanations for some processes. Moreover, Carvalho, Lima e Coquet (2004) interviewed 8 years-old children and concluded that difficulties to learn about digestion can be originate from their daily out of school experiences or instructions from parents or other adults.

Carey (1985) believes that from 9-10 years old, it is possible to observe an improvement on students' understanding about biological process. She attributes that to the acquisition of an intuitive biological theory which allows such age children to understand process like growing, reproduction and digestion from biological principles rather than as intention provoked processes. Such biological process learning is related to the beginning of children's schooling.

As digestion cannot be directly observed, in principle we assume it as a series of abstract concepts to children. One of the ways to try to teach abstract concepts to children is from the drawing of analogies. In the Cakici (2005) study implications, he asserted that children had generated analogies whilst they expressed their ideas about digestion. Therefore, he suggested teachers to stimulate their students to use analogies in order to favour their science themes understanding.

Models and analogies

Models are always part of scientific investigation. According to Gilbert and Boulter (2000), they can be defined as partial representations of objects, events, processes or ideas, that are elaborated with specific purposes like, for instance, to facilitate visualization; to base the elaboration and test of new ideas; to support explanations and predictions about the entity being modelled. In school context, teachers can elaborate models aiming at specifically favour students' understanding of a given content aspect. Such models are named *teaching models*. The most common teaching models are concrete artefacts, drawings, simulations, and analogies.

In a general way, an analogy can be defined as an explicit comparison between two domains: one unknown and the other familiar to the individual (Duit, 1991). The unknown domain, the aspect to be understood, is named *target*, whilst the familiar one is named *base*. The main principle is that, since the individual understands the base, when it is compared to the target, the target understanding may become easier.

In Gentner's (1989) view, the main attribute of an analogy is the structural alignment. One of its characteristics is the *systematicity principle*, according to which, analogies are comparisons in which relational predicates rather than object attributes are mapped. On the other hand, *mere similarities comparisons* are those in which relational predicates and object attributes are mapped.

Gentner (1989) defines other relevant types of similarities, from which we emphasise *literal similarity*, those in which both relational predicates and object attributes are mapped. Literal similarities, analogies and mere appearance comparisons constitute a continuum.

In science teaching context, analogies are mainly used as teaching models. In this case, either the teacher or the textbook provides them to students, who have to map specific desired relations – not always made explicit to them. However, analogies can also be used with a creative function, when they are generated by the students themselves. In this case, analogies can contribute to students' knowledge building since they involve students' previous ideas, and partially express their current mental models (Mendonça, Justi & Oliveira, 2006).

According to Pittman (1989), the analogical reasoning is a key aspect in the constructivist approach learning process because, when trying to elaborate his/her knowledge, the individual can search for similarities between something s/he already knows and something unknown. From a developmental approach for knowledge acquisition, the way people generate analogies depends on their general cognitive skills (thus, their age) (Wilbers & Duit, 2006), and the learning process they perform. Therefore, when students have the responsibility for generating analogies, they seem to be more productive since those analogies result from the individual's personal interpretation of the modelled entity (Wong, 1993). Although this is an individual process, it occurs in several context in which the individuals participate: scholar, familiar, social etc.

Aim

This paper aims mainly at discussing similarities about digestion generated by 9-11 years-old children while analysing the domains used to base them as well as factors that might have exerted influence in the domains selection.

Methods

The study was conducted in a Brazilian private school after it has been approved by the Federal University of Minas Gerais Ethical Committee. After obtained permission from the school headmaster and parents, 9 students volunteered to participate.

Data gathering occurred from clinical interviews in which spoken words, drawings, gestures, and general behaviour were taken into account. Each participant was interviewed twice, with an interval of nearly two months

between them. The interviews were video-recorded in order to register all children's gestures and general behaviour. In the first interview, children were initially asked about the "food route" inside their bodies. From their answers, other questions were elaborated aiming at allowing them to clearly express their ideas and to establish comparisons that could help them in this process. In the second interview, children could watch parts of the first interview video in order to analyse their previous ideas. This contributed to validate the data previously gathered and to increase the reliability of our analysis. The interviewer also asked them other questions aiming at favouring the expression of their ideas in a deep level. Although children were distributed in different classes, all of them received formal instruction about digestion during the interval of the interviews.

During both interviews, children were stimulated to draw what they were talking about. This was important because many times they had not been able to clearly verbally express their mental models, sometimes due to insufficient vocabulary. Moreover, as they were used to draw, they felt confident about using drawings to express their ideas.

The interviews were transcribed by the interviewer herself. The comparisons made by the students during the interviews were classified and analysed separately according to the types of similarity (analogy, mere appearance, literal similarity) proposed by Gentner (1989). Assuming that these types of similarity compose a continuum, sometimes we analysed the comparison taking the interview context into account. This mainly happened in cases where the compared domains shared relational predicates as well as one or more object attributes, but related in a way that did not characterise the comparison as a mere appearance one. Moreover, we analysed the base origin: whether it was from the scientific or scholar domain or it was from the daily (out of school) domain. A comparative analysis between the analogies created by each of the participants in both interviews had also been done.

Results

Next we present some results and examples of analogies generated by the children during the interviews. Following the structural-mapping theory (Gentner, 1989), we considered as analogies comparisons that presented structural relations rather than superficial similarity (like shape, size and colour). Table 1 shows the amount of mere appearance comparisons and analogies generated by the nine children in each of the interviews.

Table 1. Amount and type of similarities generated by the children in each interview.

Moment Type of comparison	First interview		Second interview	
	Mere appearance	Analogies	Mere appearance	Analogies
Total	12	10	6	8

Table 1 shows us that the nine children generated 36 similarities in total, from which 18 were analogies and 18 were mere appearance comparisons. All the participants generated similarities at least in one of the interviews.

The mere-appearance similarities were mainly elaborated during the first interview and involved comparisons between the shape of the stomach and that of a ball. On the other hand, the analogies were mainly focused on the role of some organs (mainly the stomach) and on some parts of the digestion process (e.g., the breaking of the food particles during mastication or inside the stomach, and the production of energy).

The targets, bases, and bases origin for the analogies that are discussed in this paper are in Table 2. In Table 2, we present only data from seven children, the ones who elaborated at least one analogy. In this table, children's names are fictitious ones.

Table 2. Parts of the analogies generated by the children

Moment Child	First interview			Second interview		
	Target	Base	Origin	Target	Base	Origin
Bruna	Stomach	Ball	Daily	Digestion steps	Day periods	Daily
	Stomach	Bowl	Daily	Digestive enzymes	Liquidiser	Daily
Carolina	White corpuscles	Soldiers	Daily	Stomach	Short cut	Daily
Gisele	–	–	–	White corpuscles	Soldiers	Daily
Lorena	Gastric juice, stomach and food	System composed by rain water, soil and seeds	Daily	–	–	–
Tatiana	Bladder	Coloured balloons	Daily	Vitamins	Amazon forest	Science
	Food	Oxygen liberated by plants	Science	–	–	–

As showed in Table 2, most domains used as bases for children’s analogies were from everyday experiences. Moreover, sometimes they started from a comparison between shapes and evolved to produce an analogy (by clearly emphasising some structural relation). For instance, Bruna, a ten years old girl, compared the stomach to a soccer ball. Initially, she pointed up round feature as a similarity between these two domains, but later she explained that when the ball is flatted you cannot play with it, just like when your stomach is empty, you would not have energy to play.

Most of the analogies elaborated by our study participants related either physical aspects of organs involved in digestion or structural relations between them. Moreover, the source domains they used originated from experiences outside the scholar context. This corroborates Gentner’s (1989) and Vosniadou’s (1989) conclusions that children are more susceptible to descriptive aspects or salient characteristics of compared objects.

When the analogy was based on a science/scholar domain, we realised that it had been recently introduced to students in classroom. The data also showed that, even when two children from the same class expressed domains that should have been introduced by the teacher, they understood them in an idiosyncratic way, resulting in the elaboration of different analogies. This was observed when Carolina and Gisele expressed the analogy between the white corpuscles and soldiers.

Both of them declared that their science teacher had mentioned such an analogy during one of their classes. However, in the first interview, Carolina compared the white corpuscles to the soldiers of an army who fight against the enemies, the bacteria. It is worthwhile to notice that this analogy is structurally consistent, that is, it presents several matched relationships (Gentner & Markman, 1997): white corpuscles: soldiers; fight against: fight against; bacteria: enemies; and vitamins: food for soldiers. The other child who expressed this analogy (Gisele) matched only the relation between the white corpuscles and the soldiers. As Carolina and Gisele had the same teacher, this means that they interpreted the analogy mentioned by the teacher in a different way, matching distinct relations.

Tatiana was a child who generated three analogies. In the first interview, she compared the bladder (target) to coloured balloons (base), not in terms of format, but rather considering that both can be blown up and be emptied. On account of this, we consider this Tatiana's comparison as an analogy. Her explanation concerning this analogy was very similar to the one presented by Bruna concerning the analogy between the stomach and a ball. The second comparison generated by Tatiana in the first interview matched the oxygen liberated by plants and the food we eat. Through this analogy, she intended to express the ideas that both (oxygen and food) were important for someone's survival, and that both go into and out the bodies. The last comparison generated by Tatiana involved the liberation of oxygen from the plants in the Amazon forest (base) and the liberation of energy by vitamins (target) in the human body. In Tatiana's last two comparisons, we notice an effort to relate the food nutrients with the inhaled oxygen. She generated both analogies when she was asked whether she would be able to establish any relationship between digestion and respiration processes. So, it seems that, for her, establish relationships is synonymous with match similarities. From her answers, it seems to us that she has already known something about nutrition and vegetal respiration because, according to her conceptions, the photosynthesis is the inverse process of respiration – an idea that is not acceptable in science.

Lorena compared the system composed by rain water, soil, and seeds to the system composed by stomach, gastric juice, and food. At the beginning, when she expressed this analogy for the first time, she was very confident about it. However, during the second interview, she denied it as soon as she watched the video. Such an analogy seems to have been influenced by a drawing she had made previously (when answering another question), presented in Figure 1.



Figure 1. Drawing representing the digestive system produced by Lorena during the first interview.

Lorena thought the gastric juice was like the water, the food like the seeds, and the stomach like the soil. According to her, when the water falls into the soil and reaches the seeds, it acts into them, making them germinate. In a similar way, when the gastric juice is mixed up with the food, it makes them be digested, thus becoming usable by the human body.

Lorena's case is an evidence that, from making and interpreting their own drawings, a child can use some of the drawings features to generate analogies.

Conclusions and Implications

In the data we discussed here, most of the similarities generated by children related physical characteristics of organs involved in digestion, besides structural relations. This supports our agreement with Gentner's (1989) statement that children have a tendency to map similarities based on physical characteristics of the related domains. However, in some cases we have considered that, exactly due to such similarities have been formulated by children, they could be classified as analogies. In our view, the search for a source for what they were trying to describe would be based, in principle, in salient properties, thus resulting in the mapping of object attributes. Such a map could, or not, lead them to the proposition of deep (structural) relations between the compared domains.

Our data evidenced that the base domain selection can be hard, even when a familiar domain is known. Thus, the lack of knowledge and misunderstanding of the target domain can interfere in mapping success, as Kaufman, Patel & Magder (1996) supposed. The children's tendency to categorise based only on perceptual properties may mask, or underestimate, their skill of using conceptual information in categorisation tasks (Namy & Gentner, 2002). Moreover, and still in agreement with these authors, our results suggest that comparison processes can play an important role in the integration of knowledge perceptual and conceptual aspects because superficial similarities can make the understanding of structural aspects easier.

The results presented in Table 1 made it evident that proportionally, children generated more analogies than mere appearance comparisons during the second interview, i.e., after the teaching about the theme. In addition, the relations mapped in the analogies expressed in the second interview showed a more comprehensive knowledge about digestion than those expressed in the first interview. Therefore, it seems that the teaching influenced the relations proposed by some children. We view this as another evidence that children's previous knowledge is an important aspect when they reason analogically.

Finally, our data also showed that children's performances in activities that require analogies elaboration are influenced by their creativity and imagination. The children who produced more analogies were those who showed a great interest and motivation during the interviews. Their analogies were based on several domains and drawn from complex mapping relations. On the contrary, the other children produced analogies between closer domains, or presenting several superficial aspects in common. It seems that the more object predicates mapped between the domains, the easier is the mapping.

Implications

From the results and conclusions of this study, we point out the potentiality of using activities in which students elaborate analogies in science classroom in the elementary school. However, this implies that the teachers must be conscious that each of their students takes part of their own reality and interprets the world in different ways, thus resulting that each of them can develop different models from the content introduced by the teacher. Moreover, teachers should understand that in order to promote students conceptual changes, they must know their students' previous ideas. One of the ways to know such ideas would be from analogies elaborated by the children. They can play an important role in conceptual change if the teachers establish clear relationships between them and the concepts to be learnt. We believe that when teachers start to work with analogies from this perspective, students could even start to value best their previous ideas and the comparisons they draw between them and other domains.

The children's analogies showed to be interesting tools for favouring both the expression and interpretation of their ideas about abstract phenomena. Depending on the way teachers discuss them, they can also favour students' understanding about how analogies are used in the development and communication of scientific knowledge. We view this as a promising area for both favouring children's comprehensive and authentic science learning and future relevant investigations.

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VISUALIZATION AND MODELLING IN THE LEARNING OF SCIENCE

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Abstract

Work on models, modelling, and visualization from four countries is drawn together to show how the learning of science is enhanced when due attention is paid to these ideas. It will be shown that visualization plays a major role in the learning of key concepts in science. Different ways in which the requirement to visualize can be incorporated into science lessons will be presented and evaluated. The teachers' role in supporting the development and use of visualization in learning will be illustrated. A wide range of means of collecting data will be shown to have a role to play in the assessment of the role of visualization in learning in everyday classrooms. Against the background of Paivio's 'Dual Coding' theory, the need to integrate the visual and verbal presentation of information will be emphasised if effective learning is to take place. The conclusion will be reached that, if the amount of content in science curricula is to be reduced, if an increased emphasis is to be placed on an appreciation of the nature of science, and if the quality of science learning is to improve, much greater emphasis must be placed on models, modelling, and visualization.

Justification for the Symposium

A model is a representation of a phenomenon (an object, idea, system, event, or process) that is initially produced to provide an explanation of some aspect of the world-as-experienced. As such, models are a major product of science. Thus if science education is to be authentic i.e. to disseminate the outcomes of science, then models must play a major role in science education (Gilbert, Boulter, & Elmer, 2000). Modelling is the process by which a model is created, initially mentally and subsequently in a form that can be shared with other people. As such, modelling is a major component of scientific methodology. Thus if science education is to introduce students to scientific methodology, then they must be taught how to create scientific models. Visualization plays a central role in the creation and learning of models. There are two meanings for the word 'visualization': as the representation of a model in the mind of an individual (otherwise called a 'mental model'); as the expression of that mental model in a form that can be perceived by others e.g. in a material form, as a diagram, in verbal description. Indeed, it is so important in all learning, especially in science, that the ability to deploy the range of skills associated with visualization in all circumstances – what has been called metavisualization or metavisual capability (Gilbert, 2005) – ought to form a core component of all science education. Although modelling and visualization are receiving increased attention (Clement, 2008; Gilbert, 2008) much research, that has both sound theoretical underpinnings by drawing on cognitive psychology, and development that has ready classroom applicability, remains to be done.

This symposium, which draws on work from 4 countries, will address six important questions that are relevant to that agenda of research and development: what part does visualization play in the learning of key ideas in science? How can activities based upon the use of / supporting the development of the skills of visualization be incorporated into science lessons? What role can teachers play in supporting the use of visualization in learning? How can the capacity to visualize be assessed? What degree of metavisual capability do science students' display? How can visual and verbal presentation of information be most effectively coordinated in the learning of key science concepts?

In the first paper, Özdemir and Ardac show how animations were incorporated into multi-activity lessons concerned with chemical equilibrium. Paper-and-pencil tests were used to show how students' metavisual capabilities both developed during the lessons and became transferable to other contexts. In the second paper, Er and Ardac recount how a web-based student-centred interactive learning environment was used in the study of the particulate nature of matter. The continuous record of student activities, which included the use of argumentation in group work with support from the teacher, showed that the use of visualization accompanied the development of understanding of the key ideas. In the third paper, Gilbert, Justi & Queiroz demonstrate how a series of lessons designed within a 'model of modelling' was used not only to teach the skills of modelling but also the concept of ionic bonding. The use of observation and interview in a group showed both the limitations to students' metavisual capabilities but also how these developed in the contexts of group work. In the last paper, Cheng and Gilbert present Paivio's 'Dual Coding' theory of learning and show how it can be used to interpret the learning of a range of science concepts that took place in routine science lessons where ideas were presented in an inter-twinned mixture of visual and verbal formats. The consequences of specific problems in students' understanding of information in the two media are discussed.

In summary, the symposium will: demonstrate that visualization plays a major role in the learning of key concepts in science; present a range of different ways in which the requirement to visualize can be incorporated into science lessons; show that teachers' use of questioning and provision of scaffolding can support the development and use of visualization in learning; suggest that a wide range of means of collecting data have a role to play in the assessment of the role of visualization in learning; emphasise the need to integrate the visual and verbal presentation of information if effective learning is to take place.

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VISUALIZATION IN LEARNING ABOUT CHEMICAL EQUILIBRIUM

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Abstract

The purpose of this study was to measure the effectiveness of animated display in helping students to understand the dynamic nature of chemical equilibrium. In order to analyze the effectiveness of animated display a pre-experimental design was implemented in an Anatolian high school in Istanbul. Data obtained from the sample were analyzed to examine the impact of animated display on students' conceptual understanding of dynamic nature of chemical equilibrium. Learning gains were determined for students who differed in terms of their performance during the animated display activity and chemistry achievement. Repeated measures of ANCOVA was used for analysis of data and results indicated that students' molecular representation of the equilibrium state were not significantly different in terms of their performance during the animated display activity. Repeated measures of ANCOVA also showed significant difference between performance during the animated display and students' understanding of dynamic nature of the equilibrium state. When the contribution of the animated display of a transfer test about different but related topic (weak acid and base equilibrium) was examined, results indicated a significant difference between activity scores and transfer scores.

Introduction

Chemical equilibrium is one of the most frequently researched concepts in chemical education research. The importance attached to the concept mainly arises from its centrality as learning chemical equilibrium is essential for developing an understanding of other areas of chemistry such as acid base behaviour, solubility equilibrium or oxidation- reduction (Voska & Heikkinen, 2000; Raviolo, 2001). A second significant factor is the frequently encountered misunderstandings of the students' generally resulting from the difficulties encountered when trying to make sense about the underlying molecular processes purely by observations at the macroscopic level. At equilibrium a chemical reaction appears to be stable at macroscopic level despite the dynamic movement of particles that can only be detected by viewing the molecular level. Similar concerns are expressed by van Driel (1998) who asserts that when observed purely at the macroscopic level students may think that nothing happens at the state of equilibrium.

Results of studies that focus on student difficulties encountered during instruction on chemical equilibrium show that students fail to discriminate clearly between the characteristics of completion and reversible reactions (Niaz, 1995), and that they have misconceptions relating to incomplete conversion of equilibrium reactions (Bergquist and Heikkinen, 1990).

Recent studies that examine student difficulties on chemical equilibrium focus on misconceptions and difficulties emerging mostly from the reversibility, incompleteness and dynamic nature of equilibrium reactions. Chiu, Chou, Liu (2002) designed a paper and pencil test with 13 items to test students' conceptions of chemical equilibrium relating to the dynamic movement of the particles, continuity and reversibility. The results indicated that students had difficulties in understanding the dynamic and random activities of particles in an equilibrium state.

Similarly Huddle & Pillay (1996) reported that students could not easily grasp the dynamic movement of the particles at equilibrium state and considered the topic to be a very abstract one. Findings by Quilez (2007) also indicate that majority of students hold a static conception of the dynamic equilibrium state, and fail to understand the dynamic nature of a system in a state of chemical equilibrium. Quilez further reports that students have a compartmentalized view of chemical equilibrium, consisting of two independent and separate parts instead of a whole system. Equilibrium was visualized as a situation in which the reaction was thought to oscillate between products and reactants. Students believed that the forward reaction went to completion before the reverse reaction started, and often thought that the rate of the forward reaction increased with time while that of the reverse reaction decreased until the equilibrium was reached. Besides, a significant number of students thought that both the forward and reverse reaction rates increased at the same rate and made incorrect predictions of the effect of various changes to equilibrium conditions. Niaz (2008) also stated that students could not differentiate between completion and reverse reactions.

Quilez (2007) and Niaz (2008) also point out to the use and interpretation of the language as an important issue in teaching and learning chemical equilibrium. Quilez showed that students found it difficult to understand the proper meaning of some words such as stress, balance, displacement, shift and equilibrium. Similarly Niaz (2008) indicated that one important point about dynamic nature of chemical equilibrium is the word equilibrium; which implies features of rest and static status, whereas chemical equilibrium involves a system that stresses the conception of dynamism and reversibility. Bilgin and Geban (2006) also argue that the word equilibrium has a static meaning which corresponds to the seemingly stable macroscopic level, whereas at the submicroscopic level the system is dynamic because of the molecular movements as well as the breakage and the forming of bonds.

Other studies also indicated concerns on the role of language in teaching and learning of chemical equilibrium, arguing that authors, teachers and students did not share the same meaning for words in the subject of chemical equilibrium (Tregust & Tyson, 1999; Pedrosa & Dias, 2000). Pedrosa & Dias (2000) examined textbooks at various levels of school chemistry to identify problematic language used in texts on the equilibrium concept and resulting alternative conceptions developed by students. Findings indicated that students had alternative conceptions on the terms “reversible reaction” and “incomplete conversion”. Furthermore most students were observed to think that substances vanished completely after a chemical reaction.

Research shows that such misunderstandings generally result from an understanding of “chemical equilibrium” that is often shaped by the already existing conceptions of chemical reactions. For example students have difficulties in explaining ‘why some reactions go to completion and why some reactions do not go to completion’ (van Driel, Verloop and de Vos, 1998) and in discriminating clearly between the characteristics of completion reactions and reversible reactions (Hackling and Garnet, 1985). One reason for these difficulties is found to be related to students’ existing conceptions on chemical reactions that are dominantly shaped around reactions that go to completion.

Research also shows that the student difficulties might result from the lack of proper instruction or teacher misconceptions. The results of a research conducted with 162 undergraduate chemistry students as well as 69 senior secondary school chemistry teachers showed that teachers also had misconceptions which may partly explain misconceptions held by the students (Banerjee, 1991).

A number of suggestions are put forth by researchers focusing on the possible ways to improve instruction on chemical equilibrium. A number of studies focus on facilitating students’ understanding about reversibility and the dynamic nature of chemical equilibrium. According to van Driel (1998) student conceptions relating to chemical reactions such as reversibility, incomplete conversion and dynamic nature of equilibrium should be revised before introducing the chemical equilibrium concept. van Driel suggests that students should initially be challenged about their existing belief that “chemical reactions go to completion” through providing contradictory examples. Research

also suggests analogies and simulations depicting the dynamic nature of chemical equilibrium as effective instructional strategies for helping student difficulties.

Research studies that question instructional strategies that may help accurate conceptualization of chemical equilibrium have examined and demonstrated the favourable role of visual displays in supporting visualization of chemical equilibrium at molecular level. Indeed the concept of chemical equilibrium is one of the main topics that require visualization tools for demonstrating the underlying molecular processes, since observations at the macroscopic level seem to reveal little insight into the behaviour at molecular level. Therefore research uses real models and computerized visual tools to display the characteristics of the molecular level in connection to the macroscopic level. van Driel (1991) has shown that a simple model of particles may be useful for students to understand microscopic properties. Similarly Kozma (2003) indicated that using technology and multimedia to show multiple linked representations and molecular models on chemical equilibrium proved to be effective. Harrison and Treagust (2000) also claimed that it is important to explain chemical equilibrium using concept process models.

Using animated or simulated displays are also found to be effective in facilitating students' understanding of chemical equilibrium, since they can effectively portray the dynamic nature of the equilibrium process. Weerawardhana, (2003) used video and molecular animations to explain liquid and gas equilibrium focusing on teacher use of visualization software designed to develop conceptual understanding of chemical equilibrium. The results of the study showed that the process of integrating visual resources with teaching strategies changed pre-service teachers' understanding and made them more confident in teaching the abstract concepts of chemistry. Owing to their favourable effect on visualization of chemical phenomena at molecular level, various simulated displays are being designed to guide student learning of the equilibrium process. Hameed, Hackling and Garnett (1993) simulated what actually happens in the equilibrium using dynamic graphics and feedback on the prediction of questions provided at this point. Huddle and White (2000) developed simulations for equilibrium reactions from the beginning of a reaction until the equilibrium is reached. Simulations show the microscopic events that lead to and maintain chemical equilibrium supported via graphical representations drawn at the end of simulations.

Rationale

The authors of the present study consider both animations and simulations to be effective tools for depicting the molecular view of chemical phenomena, because of their unique representational capabilities. Therefore the use of such visualization tools are considered to be particularly important when designing instruction for teaching a chemistry concept such as chemical equilibrium which is difficult to visualize by observable phenomena, as it is very difficult to figure out molecular processes simply by observation. As such, the present study examines the role of molecular animations in helping students understand the dynamic nature of chemical equilibrium. Molecular animations were introduced as "visual enrichment" during the final phase of an instructional sequence that consisted of 1) lab activity 2) lecture and 3) visual enrichment activity. The whole instructional sequence lasted for four class hours and included major aspects of the equilibrium process on incomplete conversion, reversibility of chemical reactions and dynamic nature of the equilibrium process. The "lab+lecture" phase (3 class hours) aimed to help students develop internal representations through presenting macro level (experimental) evidence on incomplete conversion, reversibility and dynamic equilibrium. The "visual enrichment" phase was then introduced to provide external representations and guide improvement of existing internal representations. This paper focuses on the contribution of molecular animations introduced during the visual enrichment phase of instruction. Molecular animations used during the "visual enrichment phase" were specifically chosen to help students visualize the submicroscopic view of the dynamic equilibrium state. The contribution of molecular animations was questioned by examining learning outcomes in terms of scores obtained from measures given prior to, during, and following the display of molecular animations. Analysis of data was based on comparison of student groups who differed in terms of their performance during the display of molecular animations. Additional analysis was carried out examining data from a transfer test that questioned molecular understanding on a different but related topic (acid-base equilibria).

The study specifically addresses the following questions when examining the contribution of molecular animations on students understanding of the dynamic nature of chemical equilibrium:

- Is there a significant difference between post animation measure scores of students who differ in terms of their performance during the display of molecular animations showing the dynamic nature of chemical equilibrium?
- Is there a significant difference between transfer test scores of students who differ in terms of their performance during the display of molecular animations showing the dynamic nature of chemical equilibrium?

Methods

The sample of the study consisted of two classes of 11th graders (n= 40) enrolled in a prestigious public secondary school in Istanbul. Both classes received similar instruction that included an animated display showing the molecular representations of the equilibrium state between 1) “ $N_2 + O_2 \leftrightarrow 2NO$ ” and 2) “ $NO_2 \leftrightarrow N_2O_4$ ”. The animation was displayed twice as the whole class watched them on a wide screen.

Molecular animation on the dynamic nature of chemical equilibrium

The molecular representations included in the animation show that at equilibrium 1) the reaction does not go to completion and that 2) the reaction between products and reactants continue although the number of molecules remains the same. The process is demonstrated by a series of screen shots selected from the animated display (Figure 1)

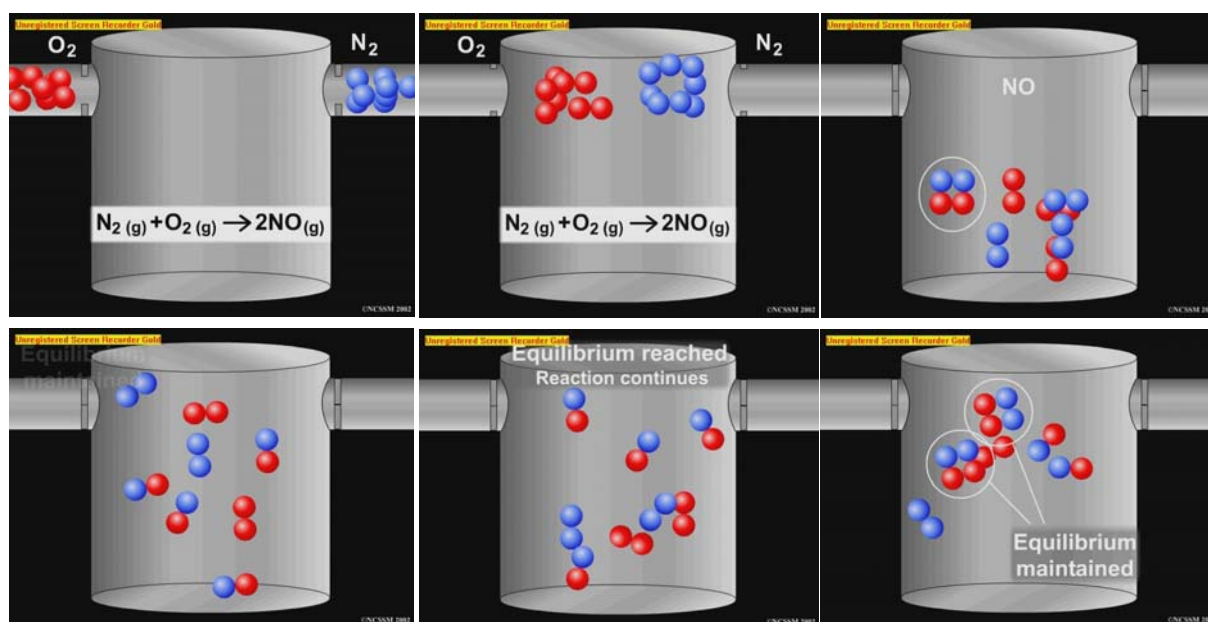


Figure 1. Selected screens from the animated display

As shown in Figure 1, the reaction initiates as N_2 and O_2 molecules start colliding to form NO molecules. The number of N_2 and O_2 molecules are decreasing as NO molecules are forming. As the equilibrium is reached, it is observed that N_2 and O_2 molecules react to form NO and NO molecules decompose into N_2 and O_2 molecules at the same rate and the numbers of N_2 , O_2 and NO molecules remain the same.

Instrumentation

In order to determine the contribution of molecular animations on conceptualization of chemical equilibrium, students' representations were examined throughout the "visual enrichment" phase of instruction. Instruments that were used to examine the changes in students' representations required students to produce verbal and pictorial explanations of chemical equilibrium before, during and after the display of the molecular animations. The assessment items were derived from a similar study conducted by Akaygun and Jones (2008).

Pre-animation measure: The instrument used before the animation included 2 open-ended items. The first item required students to explain and draw the process of chemical equilibrium. The second item included an example on the equilibrium between NO_2 and N_2O_4 and questioned the symbolic (stoichiometric) relations in connection to macroscopic (colour change) and molecular drawings at 4 successive steps following the equilibrium state. Total points obtained from pre animation measure were 14 points with item 1= 6 pts., item 2= 4 pts. for the pictorial part and 4 pt. for verbal the part

While animation measure: The instrument used during the animation consisted of a single item. This measure required students to explain what they saw on the animation screen. Students were not asked to draw molecular representations, because reproducing the content of the screen during the display was not considered to be a valid measure of their understanding. Students' explanations were categorized into "satisfactory" and "unsatisfactory" performance groups.

Post-animation measure: The instrument used after the animation included 4 open-ended items. The first two items referred to explanations emphasizing molecular representations and the dynamic nature of equilibrium. The next two items questioned students' views and opinions on the benefits of the visual display. The third item questioned specific aspects of the animation that helped students to understand chemical equilibrium concept. In the last item students were questioned if the animation had evoked any new ideas or understandings about chemistry. Only the first two items were considered when analyzing post animation data. The first item required students to explain the animation both pictorially (molecular representation) and verbally. The second item required students to explain if the reaction between N_2 and O_2 stops after reaching the equilibrium. Total points obtained from the post animation measure was 7 pts. with item 1= 4 pts. for the pictorial part and 1 pt. for verbal part, and item 2= 2 pts.

Transfer test: Additional analysis of the learning gains obtained from the visual displays was carried out using data from a transfer test that contained similar items (pictorial representations and verbal explanations) on acid-base equilibria. The transfer test included 5 open-ended items on 1) dissociation of a weak acid (HF) represented in symbolic form, 2) the state of equilibrium between dissolved and bound ions during equilibrium, 3) molecular representation showing the dissociation of a weak acid (HF), 4) molecular representation showing the dissociation of a weak acid (HF) during and after equilibrium, and 5) calculations of the dissociation constant.

Results

The data obtained from pre (before the display), post (after the display) and the transfer tests were analyzed by comparing groups who differed in terms the accuracy of representations produced during the visual display. ANCOVA was used to compare post animation and transfer test scores of students grouped in terms their performance during the animation. Grouping was based on the *while animation measure*, with students categorized as "unsatisfactory" or "satisfactory" based on their responses. Missing data (one student who was absent during the display) was excluded from analysis.

The first research question focused on the difference between post animation measure scores of students who differed in terms of their performance during the display of molecular animation on chemical equilibrium. Initial analysis compared post performance of students in "satisfactory" and "unsatisfactory" groups. ANCOVA

was used to compare groups (taking pre animation scores as a covariate) in terms of the total score and separately for each item of the *post-animation measure*. Table 1 shows descriptive statistics comparing post animation mean scores for groups who performed “satisfactory” and “unsatisfactory” during the animation.

Table 1. Post animation mean scores for groups who performed “satisfactory” and “unsatisfactory” during the animation

Post Animation Measure		Groups in terms of performance during animation	
		Satisfactory (n=26)	Unsatisfactory (n=13)
Item 1 (pictorial)	Mean	3.00	2.31
	S.D	1.55	1.65
Item 1 (verbal)	Mean	.42	.08
	S.D	.504	.277
Item 2	Mean	1.96	1.54
	S.D	1.90	.660
Total	Mean	5.38	3.92
	S.D	1.74	2.02

Although the mean for the post animation total score is observed to be higher for the group who performed “satisfactory” during the animation (M= 5.38, S.D= 1.74) as compared to the “unsatisfactory” performing group (M= 3.92, S.D= 2.02), the difference was not found to be significant. ANCOVA results (when pre animation scores are taken as covariate) indicate no statistically significant difference between “satisfactory” and “unsatisfactory” groups, $F(1,36) = .422, p = .520$. However both groups seem to show an adequate understanding of the equilibrium concept, since the mean score for each group was found to be above the average points (3.50 points) calculated for the post animation measure. Results also indicate the pre animation score as a significant factor contributing to variance in post animation performance, $F(1,36) = 12.56, p = .001$.

When items of the post animation measure were analyzed separately, different results were obtained for the two items. The first item required students to explain the animation using molecular representation and verbal statements. Students who were classified into “satisfactory” and “unsatisfactory” groups based on their performance during the animation were observed to be similar in terms of the molecular representations and verbal statements they used to explain the animation. The results showed that the students could produce molecular drawings to represent the animation content regardless of their performance during the animation. Further, ANCOVA results indicated significant main effect of the pre animation measure on post performance (pictorial part of the first item), $F(1, 36) = 13.931$. Such a finding suggests that the proficiency in producing molecular drawings representing the animation on chemical equilibrium is more of a function of pre-animation scores rather than performance during the animation. Figure 2 shows molecular representations that exemplify student drawings by students showed “satisfactory” and “unsatisfactory” performance during the display of the animation.

The score for the verbal explanations was observed to be very low for both groups. The mean score for each group was found to be below the average points (0.50 points) calculated for the verbal part of the first post animation item, $M = .42$ and $M = .08$ for “satisfactory” and “unsatisfactory” groups respectively. One possible explanation for low performance might be the repetitive nature of the item that requires both molecular and verbal explanations. Students might have considered the verbal part as redundant after producing molecular representations.

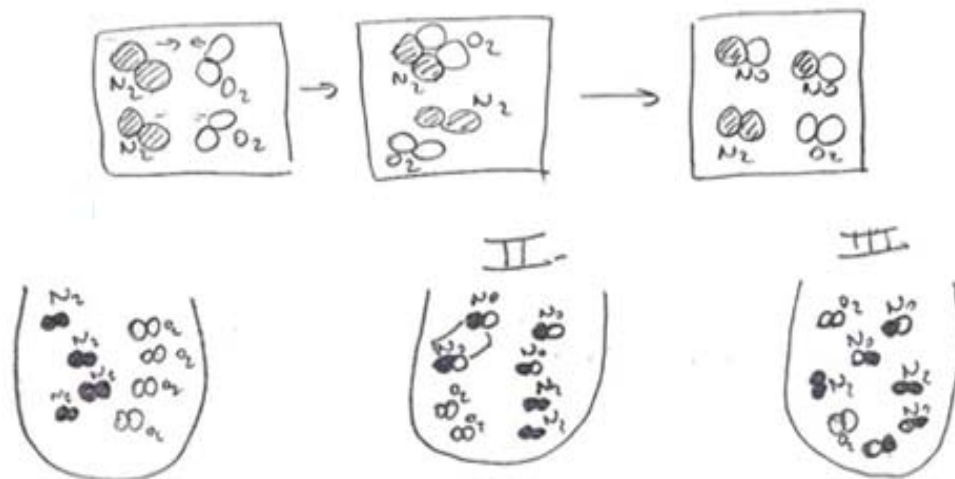


Figure 2. Molecular drawings representing the animation on chemical equilibrium produced by students who showed “satisfactory” (upper row) and “unsatisfactory” (lower row) performance during the animation

Analysis of the second post animation item indicates that performance during the animation might contribute to students’ understanding of dynamic equilibrium. ANCOVA results indicated statistically significant differences between “satisfactory” and “unsatisfactory” groups ($M=1.96$, $S.D=.196$ and $M=1.54$, $SD=0.660$ respectively) in terms of post animation (item 2) scores, $F(1,36)=8.57$, $p=0.006$. Figure 3 exemplifies student answers to the second item of the post animation measure by students who showed “satisfactory” and “unsatisfactory” performance during the display of the animation.

Results from group comparisons imply that the “satisfactory” performance group who evidenced an understanding of the animation during the display 1) performed similar to the “unsatisfactory” performance group when drawing or explaining the contents of the animated display , 2) performed significantly better than the “unsatisfactory” performance group when explaining the dynamic nature of chemical equilibrium.

Second research question focused on the difference between transfer test scores of students who differed in terms of their performance during the display of molecular animation. This analysis was conducted in order to examine the long term effects of molecular animation showing the dynamic nature of chemical equilibrium. Results would be considered to favour the contribution of molecular animations if students who had evidenced an understanding of the animation during the display (received high scores from *while animation measure*) scored higher in the transfer test as compared to those who received lower scores from the *while animation measure*. ANCOVA was calculated to compare “satisfactory” and “unsatisfactory” groups (based on their performance during the animation) in terms of the scores obtained from the transfer test. Chemistry achievement (grade average of the previous two years) was taken as a covariate in order to control for the differences in achievement. Table 4 shows descriptive statistics comparing transfer test scores for groups who performed “satisfactory” and “unsatisfactory” during the animation.

Results indicate that the mean for the transfer test is higher for the group who evidenced an understanding of the animation during the display ($M= 6.42$, $S.D= 2.23$) as compared to those who showed “unsatisfactory” performance during the animation ($M= 5.00$, $S.D= 2.92$). ANCOVA results (when chemistry achievement was taken as a covariate) indicate that the difference was significant at $p= .049$ level, $F(1,36)= 4.139$.

Table 2. Transfer test means for groups who performed “satisfactory” and “unsatisfactory” during the animation

Groups in terms of performance during animation	n	Transfer Test	
		Mean	S.D.
Satisfactory	26	6.42	2.23
Unsatisfactory	13	5.00	2.92

Results indicated that students’ understanding of chemical equilibrium improved substantially as a result of these lessons and that their answers, especially those in the ‘transfer’ element of the assessment, showed clear indications of the value of the visual representations.

Conclusions and Implications

This study used an animated display in helping eleventh grade students visualize the dynamic nature of chemical equilibrium. In order to determine the effectiveness of the visual display, students’ performance while watching the animation was used as a criteria in forming groups (“satisfactory” and “unsatisfactory” groups) that were compared in terms of their post performance (post animation measure scores and transfer scores).

ANCOVA results comparing post performance of groups (taking pre animation scores as a covariate) indicate that the groups (“satisfactory” and “unsatisfactory”) are statistically 1) similar in terms of their post animation performance on molecular representations and verbal explanations about chemical equilibrium, 2) different in terms of their post animation performance on verbal explanations of the dynamic nature of equilibrium, 3) different in terms of their transfer scores. ANCOVA results also indicate that pre animation performance is significant in explaining variance in post performance.

Results imply that students could recall and draw molecular representations of the animation regardless of their performance during the animation. Further both groups could score above the average points calculated for the post animation measure. This result suggests that the animation was clear, straightforward and easy to recall. It also implies that the animation was effective in communicating the key features of the submicroscopic view, as both groups were observed to be similar at a high performance level (above the average points). However, although both groups show some understanding of chemical equilibrium by recalling the contents of the animation and producing acceptable drawings (in the first item of the post animation measure), the groups were significantly different in their understanding of dynamic equilibrium (the second item of post animation measure). One possible explanation of this finding might be the differences in the difficulty level of each item. For the first item (representing the contents of the animation) students might have recalled and reproduced some of the visual elements displayed on the screen, without real understanding. However the second item requires deeper understanding of the equilibrium phenomena (further interpretations of what is observed) than simply mimicking the contents of the screen. Therefore it might more effectively discriminate between learning outcomes of students who show “satisfactory” or “unsatisfactory” performance during the display.

The significantly higher results observed among students who showed “satisfactory” performance while working with the animation is considered to be an indication of the effectiveness of the animation particularly for those students who indicated an understanding during the display. It seems that the animation was effective in helping those visualize how the reaction between products and reactants took place at equal rates at the sub microscopic level. One implication of this result might be the importance of encouraging students to make sense of their observations during the display in order to increase the effectiveness of the presented visual.

Similar results were obtained for student outcomes in the transfer test. When the contribution of the animated display on the performance from a transfer test about different but related topic (weak acid and base

equilibrium) was examined, the results indicated that students, who showed “satisfactory” performance while working with the animation, had significantly higher transfer measure scores regardless their chemistry achievement. In other words significant difference in transfer scores of “satisfactory” and “unsatisfactory” performing groups during animation are due to the involvement in the ongoing activity rather than their chemistry achievements.

On the whole the results indicated that the animation was effective in helping students visualize chemical equilibrium at molecular level. All students were able to draw the contents of the animation at an “acceptable” level (scoring above the average point) indicating that the animation was effective in conveying some understanding concerning the molecular view of the equilibrium process. However, there were differences in learning outcomes of students who differed in terms of their performance during the animation. Students who seemed to be more “involved” (showed “satisfactory” performance) during the animation indicated better understanding with regard to the dynamic nature of equilibrium and the transfer test scores (on acid-base equilibria). This result implies that active involvement and “time-on-task” can be important factors when examining the contribution of visual on students learning. The results also suggest that the contribution of an animated display may be increased by reinforcing student involvement during the animation by further prompting and questioning.

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A WEB-BASED LEARNING TOOL THAT EMPHASISES THE ROLE OF VISUALS IN SUPPORTING ARGUMENTATIVE CLAIMS

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Abstract

The primary aim of this study is design and development of a web based science learning tool that follows instructional design guidelines derived from current practices of constructivist approach and argumentation in science education. The tool is designed to help students develop conceptual knowledge on unit of particulate nature of matter and also gain argument building skill which is an important element of science education. The tool includes a variety of interactive learning activities that focus on visual elements designed to support an argumentative claim. The study also includes a preliminary effectiveness study with teachers in order to get feedback and carry out revisions for the tool and a pilot study with a small group of students to get initial data on the effectiveness and usability of the system. The results imply that the tool might help conceptual understanding of particulate nature of matter. Students produced more accurate molecular drawings with less macroscopic interference for representing matter at submicro level after working with tool. However the results also imply that further work might be required to improve the contribution of the tool in guiding development of argumentation skills.

Introduction

This study aims to design and develop a web-based learning tool for science based on the major principles of the constructivist approach. Turkey, like many other countries has based its new “Science and Technology Course” curriculum (MNE, 2005) on major principles of the constructivist approach that considers both the suggestions from current theories of learning as well as competencies required by the information age societies of the 21st century. The “Science and Technology Course” curriculum that has been redesigned with this perspective suggests constructivist methods that favour student-centred, process-oriented, problem-based, interactive processes that provide individually prescribed learning environments through the use of multiple representations. This contemporary approach that places the students in the centre of the learning environment, takes advantage of recent technological advances to give rise to a number of instructional models and theories (Reigeluth, 1999). These models have frequently favoured web-based learning environments owing to the facilities that an electronic medium can provide to support important components of student-centred learning processes (e.g. multiple representations, interactivity, guidance and communication).

Theoretical Background

The design of the learning tool in the present study is primarily based on the common features of web-based constructivist learning environments. The tool is designed to support the development of scientific thinking using major components of the argumentation method and related research (Erduran, Simon & Osborne 2004). The argumentation process requires the students to support their claims (e.g. on the solution for a problem case) using related evidence. This framework is used in the design of the tool in terms of three major components specified as

“the problem state”, “views and/or claims” and “related evidence”. During the process the students are expected to identify the claim that mostly aligns with their thoughts and support this claim using evidence included in the learning environment. The evidence is derived from various activity areas that were developed by using multiple representational facilities of the electronic medium.

Visual elements are dominantly used to formulate the variety of evidences included in different activity areas. The use of visual elements was particularly favoured in the design of this learning tool due to the increasing importance of visualization in science learning. The growing importance placed on visualization during science learning can largely be explained by the close proximity between what science is and how it should be learned, as both generation and conceptualization of science requires visualization of phenomena at macro and submicro levels, Gilbert (2005) defines visualization in terms of internal and external representations and elaborates on how the modes or submodes these two representations interact to facilitate (or slow down) science learning. According to Gilbert it is particularly important to understand the role of external representations on learning science, because interactive computer technologies now enable visualization of scientific phenomena in such a way that would either be impossible or hard to achieve by other means. According to Pea et al. (1999) visualization tools can take advantage of the power of technology to help students understand hard problems and learn concepts and ways of thinking previously accessible only to experts. They claim that it is hardly possible to demonstrate the connection between the macro and micro worlds in the sciences without the use of interactive technologies. Indeed visualization emerges as an important principle in the design of recent instructional models (particularly web-based learning environments) as science educators can now more readily use visualization tools by exploiting representational capabilities of computerized environments.

The learning tool outlined in the present study invested on the capabilities of the interactive computer technologies when trying to make use of visual elements designed to support an argumentative claim. Apart from the emphasis placed on the use of visuals, this present study was inspired by major principles governing “Knowledge Integration Environments” (Slotta & Linn, 2000). Knowledge Integration Environment (KIE) is an internet based science learning set that is designed according to “scaffolded knowledge integration” principles. During the instructional process, students choose between two theories and explore evidences in KIE environment (text, video or graphic formats) or suggest evidences from their own lives that may support one of the competing theories. Students are guided as they categorize, construct and revise their evidences. This software serves as a knowledge representation tool that models expert thinking because students examine scientific arguments of science experts. It also promotes collaborative exchange of ideas, group work and communication with others.

Inspired by existing instructional models, the present study was an attempt to develop a web-based science learning tool that guides students through an argumentation lesson as they try to collect evidence to support their starting claims. The learning tool is designed to cover the topic on “particulate nature of matter” in the sixth grade “Science and Technology Course” curriculum of Turkey. “Particulate nature of matter” is chosen as the unit of study for a number of reasons. First it is one of the core concepts that is essential for understanding of subsequent more advanced topics. Second majority of students are reported to have difficulties in understanding particulate ideas (Gabel, 1993). Third suggested instructional strategies for helping students develop scientifically acceptable particulate ideas can more effectively be achieved by the use of visualization tools enabled by the capabilities of computer technologies.

Johnson (1998) claims that it is the “teaching” rather than students’ capabilities that restrict successful progression towards an accurate understanding of particulate ideas. According to Johnson particulate ideas form part of a progression towards a scientifically acceptable particulate model, the development of which can be improved through appropriate instructional decisions. Research consistently indicates that students will develop an accurate understanding of particulate ideas and underlying phenomena when instruction establishes the links between macro-submicro-symbolic levels (Tasker, Chia, Bucat & Sleet, 1996).

Computer technologies provide powerful means for establishing the links between macro-submicro-symbolic levels, through their representational capabilities that enable simultaneous display of multiple representations. The results of our previous studies (Ardac & Akaygun, 2004, Ardac & Akaygun, 2005) indicate that instruction that uses computer technologies to establish connections between macro-submicro-symbolic levels can significantly increase students' particulate understanding.

Methods

The present study uses findings from past research when designing a web-based science learning tool (WbSLT) on "particulate nature of matter". Special interest is given to microscopic representations in order to help students visualize particulate nature of matter. Students are encouraged to give meaning to each single visual display in connection to the main idea, with each visual serving as evidence in supporting the starting claim. This is expected to improve understanding through reinforcing the links between separate representations.

The main aim of the study is the design and development of the system and instructional materials related to a selected sample unit on 'particulate nature of matter'. The tool was designed to develop students' conceptual understanding on the selected unit as well as to engage them in activities that support the development of the argumentation skills. The study also aims to provide initial data on the usability and effectiveness of the tool.

In order to collect preliminary data on the effectiveness of the tool a pilot study was carried out on a small group of students. The aim of the pilot study was to determine student gains in terms of 1) conceptual understanding on particulate nature of matter and 2) basic argumentation skills.

Development of the Web-based Science Learning Tool (WbSLT)

Design guidelines of the WbSLT are derived from current constructivist design models, suggestions coming from argumentation studies and usability principles of interactive learning environments. The design and development process covers three phases on 1) student activity environment, 2) learning activities to be included in each activity room, 3) teacher monitoring and administration environment.

Student Activity Environment

The main components of the student activity environment are "topic introductory screens" and "activity rooms". As students follow activities in activity rooms, they try to collect evidence to support their solution for the main problem and build up related arguments using the collected evidence. Activities are designed to help students investigate simulations and interactive experiments (in investigation and video room), observe video demonstrations (in video room), read additional textual and pictorial documents (in expert room), discuss with their classmates and the teacher (in discussion room), complete educational games (in game room) and other assessment activities (in competition room). Activities in investigation and video room mainly use predict-observe-explain (POE) strategy in order to reinforce students to generate tentative answers (build hypotheses), by making predictions, testing their predictions, and thinking about their observations. Students' responses to each task are recorded by the system and can be monitored by the teacher.

Learning Activities for Selected Unit

The unit starts with a problem statement which requires students to select the alternative which they consider to be the most accurate molecular representation of evaporating chalky water (Figure 1a). Alternative answers are original student drawings that are adapted from the study of Ardac and Akaygün (2004). Students' responses are accepted as their claims about the "particulate nature of matter". Once the students specify their claims they are directed to the next screen that provides a suggested sequence for visiting activity rooms as they try to collect evidence to support their starting claims (Figure 1b).

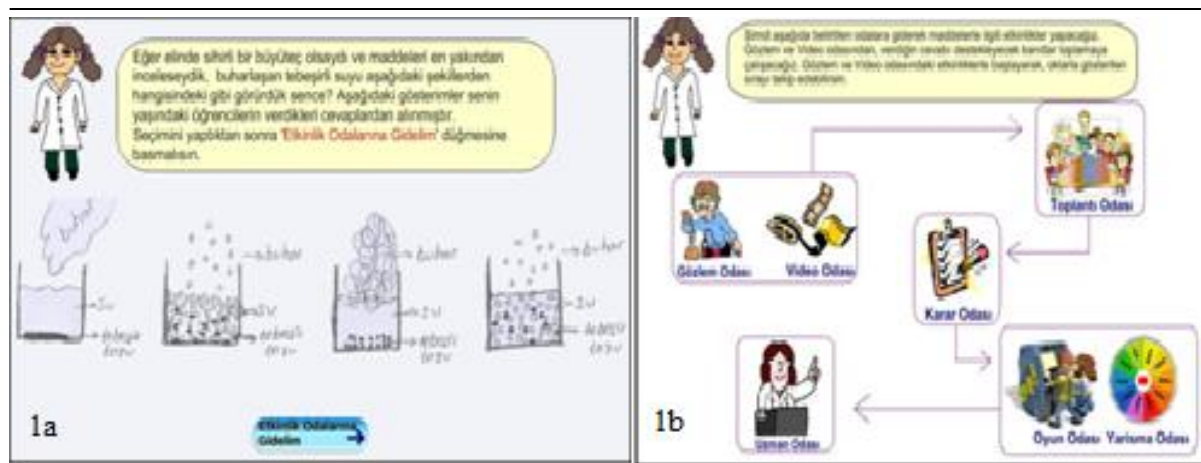


Figure 1. Introductory screens of WbSLT.

The investigation room includes two interactive experiment simulations on compressibility differences of liquid (Figure 2a) and gas and dissolving salt in pure water (Figure 2b) where both experiments use POE format and enable zooming into the molecular view. A third interactive activity provides opportunities for examining different matter at molecular level.

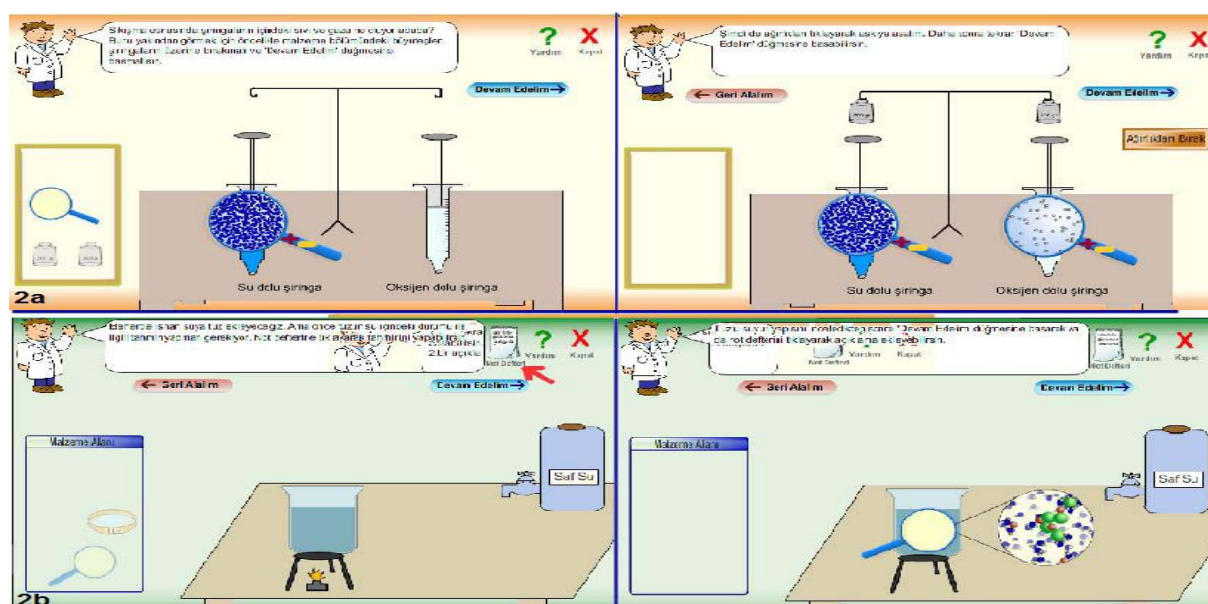


Figure 2. Interactive experiments on (a) compressibility and (b) evaporating salty water.

The video room has three video-based activities that include a demonstration using POE format to show dispersion of ink in water, and two video clips showing 3- dimensional molecular representations of evaporating water and salty water (from VisChem Project by Tasker, et al., 1996). The discussion room is the place where students are expected to share their finding which is collected from activity rooms with other peers and teacher provides feedback for them. A forum like discussion board for the use of teachers and students are designed to support collaboration and group work in argument building process.

Decision room is the place where students view their answers for initial question/problem, their responses to POE questions during the activities carried out in investigation and video rooms and a list of explanation statements. The explanation statements that are generated by students serve as evidences that may either support or oppose their main claim. As students observe their responses presented in the decision room, they are expected to decide on the final answer/ final argument and write a decision report on given template.

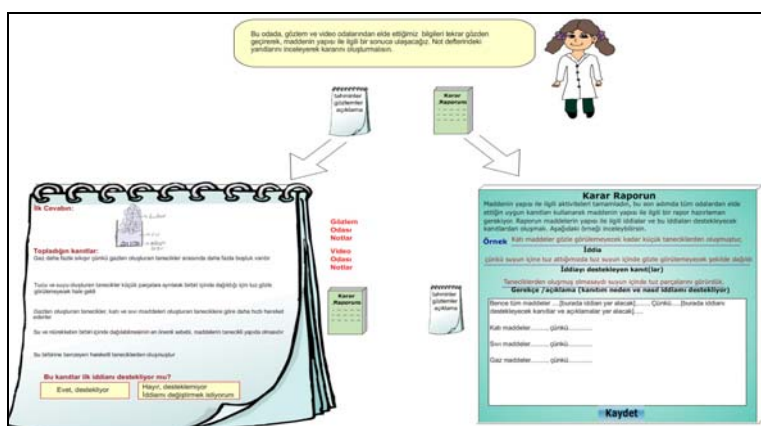


Figure 3. Decision room and its components.

The *game room* includes a matching game that requires students to drag appropriate particulate representations of matter in solid (ice), liquid (water) and gas (water vapour) phase. The correct and incorrect moves are counted and recorded by the system. The *competition room* serves as an assessment module for the content knowledge and it is designed to evaluate students' knowledge as they complete the activities in previous rooms. That module is presented as a competition using layout that resembles popular competitions broadcasted in television channels (like "Wheel of Fortune" is used for the present study). Immediate feedback is provided by the system as students answer questions. The *expert room* includes textual and pictorial materials that provide summary and supplementary information for activities in other rooms. New technologies and developments, scientific facts and information that are not highlighted in activities of other rooms are included into the expert room.

Teacher Monitoring and Administration Environment

Teachers' guidance is an important component of WbSLT. The system allows teachers to check students' responses to all questions or tasks in the system. Teachers can access student activity environment and teacher monitoring environment. In teacher monitoring environment, they can check student answers and create discussion topics for the selected unit. Teachers can also get question statistics and student answer reports; they can see the list and the number of correct and incorrect answers for each question in activity rooms. Site administrator is the third type of user who is responsible for assigning teachers (assigning user name and passwords for teachers), defining the rooms, activities in each room, and defining tasks or questions and alternatives.

Teacher Trial and Revisions

This part of the study was carried out with in service teachers during the late development phase to evaluate the effectiveness of WbSLT for initial revisions. Three science teachers working in different private secondary school participated in the initial trials of the tool.

Teacher views during the initial trials of the tool were collected using a semi-structured interview. The interview contained 6 open-ended questions on scientific accuracy, weaknesses, strengths, usability of the tool, and further comments. Each session lasted for approximately 50-70 minutes. The data indicated that WbSLT required minor revisions (such as wording of questions and related alternatives, sizes and types of apparatus). The teachers believed that the tool could successfully be used in different phases (particularly introduction, review and enrichment) of instruction. Data obtained from teachers was used to carry out necessary revisions of the tool. Development phase was finalized after the revised tool was ready for the pilot study.

Implementation and Pilot Testing

The aim of the pilot study was to carry out a formative evaluation study to detect the effectiveness of the tool in improving students' 1) conceptual understanding on "particulate nature of matter" and 2) argumentation skills.

Participants

The participants of the pilot study consisted of 8 primary school students, 4 girls and 4 boys, who had completed 5th grade (11 years old). The participants were selected on the basis of convenience.

Data Collection Tools

Three sets of data were collected to carry out preliminary analysis of WbSLT. The first set was used to assess learning gains in conceptual understanding and consisted of pre and post tests on conceptual understanding of the topic. The second set of data was based on a semi-structured interview that required students to suggest evidence for two claims depicting scientific phenomena. The third set of data was collected by the usability questionnaire.

Pre - Post Test on Conceptual Understanding of "Particulate Nature of Matter"

The test consists of two open ended items that required students to draw molecular representations of selected scientific phenomena. The first question aims to measure students' understanding of the compressibility of gases. Students were given a flask that contained oxygen gas with a movable piston resting on top of the flask. The students were asked to draw the position of the piston (at macro level) and represent oxygen gas (at submicro level) before and after some weight was released onto the movable piston. The second item required students to draw molecular representations for water, salty water, evaporating water and evaporating salty water.

Semi-Structured Interview

The interview was carried out in order to determine whether students could provide any evidence to support the given claims and if they do so, whether they could also provide warrants or explanations that connect the claim and evidence. Two items (claims) were presented during the interview. The first claim was about "particulate nature of matter" and required students to agree or disagree with the statement: "All matter is made up of invisibly small particles with some empty space between them". Then the students were prompted to support their position by the questions: "How do you know that this claim is true/false? How could you persuade a person or a friend to accept your position?" The second claim was about the earth spinning around. The students were again prompted to explain why they did (or did not) agree with the claim, giving evidence for their position.

Usability Questionnaire

Usability questionnaire was used to collect data about the usability of the system. It consists of 10 items (9 Likert-type, one open-ended) designed to understand the ease with which users can manage to work with the system.

Procedure

The participants used the tool individually during separate sessions. Initially, each student was briefly introduced to the system and was informed about the aim of the study, procedure and the tasks that must be carried out during the working session. Each student took the pre-test (approximately 10 minutes) immediately before starting to work with the tool. Sessions typically lasted for one class hour. Participating students completed all the activities. After the session, the usability questionnaire and the post-test were administered (25-30 minutes). The interview sessions were conducted immediately after the completion of the post-test.

Data and Results of the Pilot Study

Data were analyzed according to students' learning gains in conceptual understanding of selected topic, students' use of evidences to support claims and usability of the tool.

Learning gains in conceptual understanding of "particulate nature of matter"

Data obtained from each item of the pre and post tests were analyzed to identify the change in students' particulate understanding of matter. The first item assessed understanding of compressibility property of gases in terms of drawings produced at macro and submicro levels. At macro level the students were asked to draw what would happen if some weight was released on a piston positioned at the top of a closed flask filled with oxygen gas.

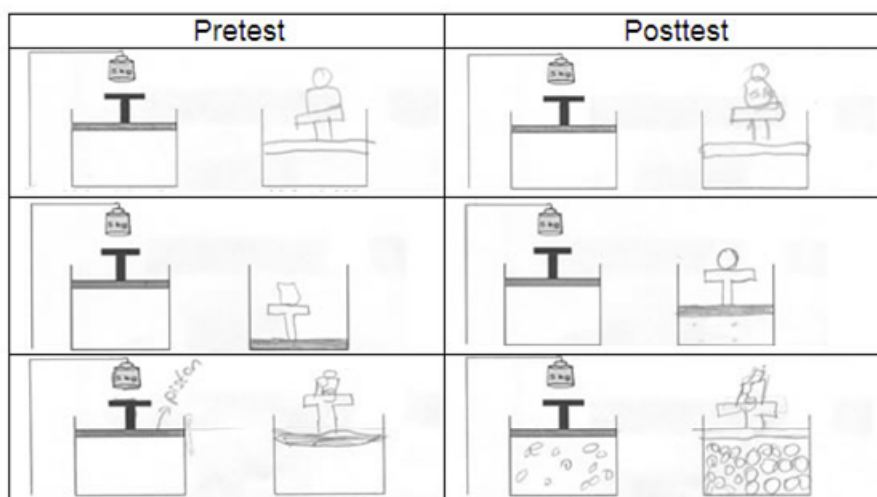


Figure 4. Student drawings representing compressibility of oxygen.

Figure 4 exemplifies 1) drawings that were correct both in the pre and post test (first row), 2) drawings that indicate a change towards more accurate understanding in the post test (middle row), and 3) erroneous representations both in the pre and post test (bottom row).

According to the results 1) three students produced accurate representations both in the pre test and the post test, 2) four students showed a change towards more accurate representations, and 3) one student produced erroneous representations both in the pre test and the post test.. Molecular representations before and after compression were questioned in the second part of the first item. Drawings were considered to be erroneous or inaccurate if 1) there is no decrease in the volume of gas after compression, 2) drawings indicate macroscopic interference, 3) the distance between particles does not change. The results showed that all of the students had presented particulate understanding in post measures. Additionally when we move from pre to post-test there was a positive change in students' representations which was observed as a shift from either erroneous to accurate representations (exemplified in Figure 5 upper row) or towards more refined forms of representations in posttest (exemplified in Figure 5 lower row).

Second item in pre and post test required students to draw the molecular representations of ice (solid), water (liquid), evaporating water (liquid and gas), salty water (solid and liquid), evaporating salty water (solid, liquid and gas). Drawings were considered to be accurate representations if 1) matter is represented in particulate form, 2) the particles are distributed randomly, and 3) there is no macroscopic interference (e.g. drawing borders, adding fumes or smoke for gases, using dots and points for representing salt).

The results indicated that nearly all students moved from drawings dominated by macroscopic interference in pre test to more refined and accurate representations in the post test (Figure 6).

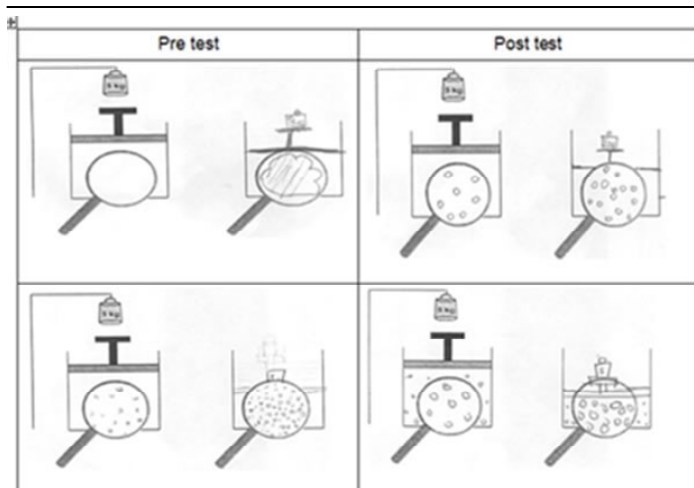


Figure 5. Molecular representation of oxygen before and after compression.

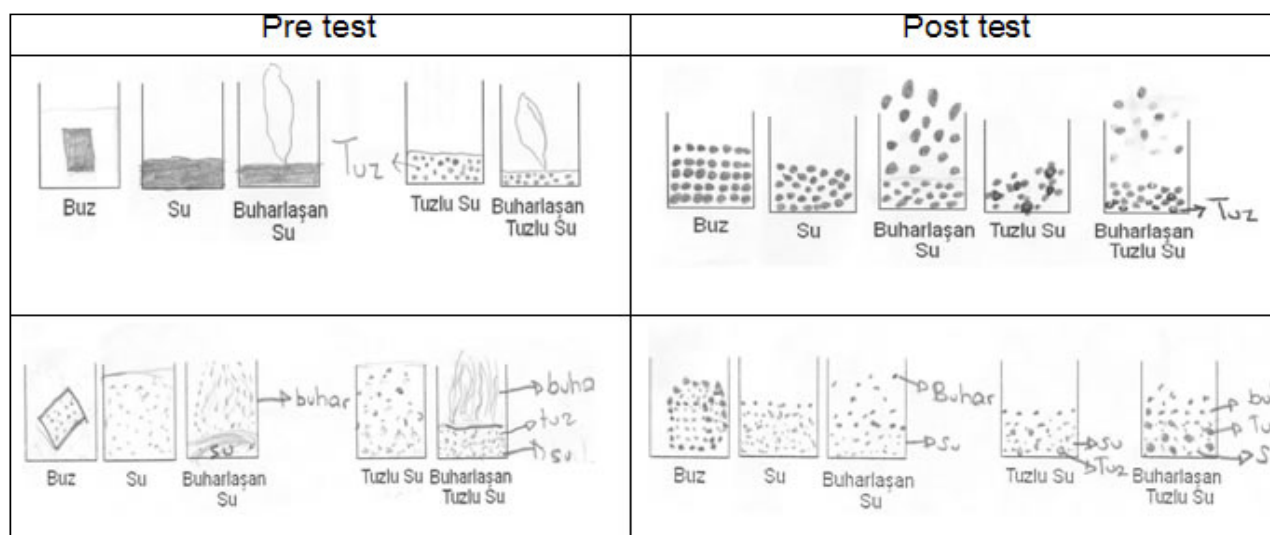


Figure 6. Student drawings representing ice, water, evaporating water, salty water, evaporating salty water at submicro level.

Supporting claim using evidence

Data obtained from the semi-structured interviews were used to understand if the system was effective in helping students build up argument statements. During the interview students were asked to state their position (agree/disagree) in response to two items (claims), and support their position by giving evidence. The first claim was about “particulate nature of matter” and the second claim was about “spinning of the earth”.

Interview data indicated that all students were in agreement with both claims, and all students except one could provide some evidences to support the two claims. However, mostly some prompting was necessary before students came up with evidence statements. Students generally referred to the tool as a source of information for collecting evidence. The tool was mentioned either directly (e.g. “I can explore the web-based tool and I give the address to my friend to persuade him” or “we saw in game room and in compression experiment”) or indirectly by mentioning the devices used in the activity areas (like magic lens which was mentioned by four of the eight students). Two types of evidence, either investigation-experimentation or visual image was apparent among student responses, with more detail being provided for visual evidence. The only distinct answer was given by one of the students who mentioned “authority” as a source for evidence. When examined for the type of warrants, the data indicated that students did not provide the link between the evidence statements and the claim. In rare cases some

connection was implied particularly when the evidence was in visual form. This might be because the connection between visual evidence and related claim is more obvious. For instance one student said: “In order to persuade my friend about this claim, I show a flask filled with air. He cannot see anything inside the flask, it is like empty. But if he looks into the flask using a special microscope, he can see the air (particles), therefore he can be persuaded”. The more easily perceived connection between a claim and visual evidence can be an important benefit favoring the use of visuals during an argumentation process.

Analysis of interview data for the second claim (“earth spinning around”) revealed similar results. Students frequently based their evidence on either visual data like “photographs and video records taken from satellites” or observations like “formation of days and nights”. Just like the previous case “particulate nature of matter” there was a single (but different) student who referred to authority (“a lot of people are saying this”) as a source for evidence.

Finally the results implied that students were not very fluent in providing evidence to support a scientific claim as prompting was generally necessary before students suggested an answer. Further, the students generally found it difficult to express why specific evidence supported the given claim especially when the evidence was data from an experiment because none of the students tried to explain how experimental evidence functioned in supporting “particulate nature of matter”.

Usability of Web-based Science Learning Tool

Usability of the tool was examined using data from “Usability Questionnaire”. “Usability” points (increasing usability from 1 to 5 pts.) for each item of the questionnaire indicated most of the components were comfortably used by the students. The students found it most difficult (mean usability score= 3) to complete the report in the decision room.

Discussion and Conclusions

The results of the pilot study provide us some insight as to how the WbSLT might contribute to the development of conceptual understanding and argumentation skills. Although the number of participants are quite low (n= 8) the consistency of results allow us to derive some implications about possible benefits of the tool and how it might be revised for future use. Results obtained from the pilot sample imply that the tool might help conceptual understanding of particulate nature of matter. However the results also imply that further work might be required to improve the contribution of the tool in guiding development of argumentation skills. Although, students did indicate improved particulate understanding by producing more accurate representations, they seemed to experience difficulties when using experimental data to support the claim on particulate nature of matter.

It is possible to draw conclusions about contributions of the tool on the development of argumentation skills by considering students’ responses to interview items that required them to provide evidence for two claims (on particulate nature of matter and the earth’s spinning). Students frequently used visual sources (such as molecular animations observed through the magic lens, video records or photographs) as evidence to support the given claims. Although representations at submicro level are expected to guide students’ understanding when interpreting the results of an experiment and thus help them to establish the link between data and the claim, students generally preferred to refer directly to the molecular view as evidence rather than using the molecular view to interpret data from experiments. Such a finding implies that further guidance is required to help students generate warrants by helping them “see” how data is connected to the claim. We consider this to be an important implication when revising WbSLT for improvement. One possible revision relates to the sequence with which the activities are presented to the students. Priority might be given to visuals that directly represent matter at submicro level which are then embedded in more complex animated or simulated experiments, as although students found it difficult to generate warrants for establishing the connection between evidence and claim, they could more readily provide warrants in the case of molecular representations which exhibit an obvious link to the claim.

Another result that seems to be important for revision of the tool was obtained from the usability data. Although students found the system and sub-parts easy to use, most of the students felt that filling the decision report was relatively more demanding. This result may have different explanations. One explanation is that students might be experiencing difficulties in connecting parts of a whole. Although they understand the evidence per se, they may not easily locate it within the big picture. Thus separate activities may remain isolated or vague in terms of their relevance or connection to the main idea (starting claim). A second and related explanation may be the students' inability to see the wholeness of the argumentation process. Therefore future revisions of WbSLT might include 1) more emphasis on how evidence from each activity can be used in connection to the starting claim, 2) additional guidance that encourages students to reflect on the collected evidence as they leave various activity rooms, 3) an argument map that helps students trace their location within the argumentation process and/or 4) an exercise in decision room that requires students to construct an argument map that schematically represents the relation between claims, evidences and warrants.

The preliminary results obtained from a small group of students were encouraging and inspiring, because the data helped us derive some implications as to the possible ways through which WbSLT could be improved. However, because sample size was very small, and because the existing data did not reveal sufficient depth, future studies are required to try out the need and possible effects of the revision ideas derived from this preliminary study.

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THE USE OF A MODEL OF MODELLING TO DEVELOP VISUALIZATION DURING THE LEARNING OF IONIC BONDING

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Abstract

The natures of models and modelling are rehearsed. The central role played by visualization in modelling is discussed and the importance of acquiring metavisual competence is argued for. A 'model of modelling' is summarised and a sequence of activities embodying it is outlined. The results show that a group of Brazilian students learning about the ionic bond did use or develop the skills of metavisualization.

Introduction

Modelling and Visualization in chemistry and chemical education

Humans have evolved the ability to mentally 'cut up' the world-as-experienced into chunks about which to think. This process of chunking is modelling and the products of the mental actions that have taken place are models. Science, being concerned with the provision of explanations about the natural world, places an especial reliance on the generation and testing of models.

Models can be represented in one or more of five *modes*. These modes are:

- The *concrete (or material) mode*. This is three-dimensional and made of resistant materials e.g. a plastic ball-and-stick model of an ion lattice.
- The *verbal mode*. This can consist of a verbal or written description of the entities of which the representation is composed and the relationships between them e.g. of the natures of the balls and sticks in a ball-and-stick representation. It can also consist of an exploration of the metaphors and analogies on which the model is based, e.g. 'covalent bonding involves the sharing of electrons'.
- The *symbolic mode*. This consists of chemical symbols and formula, chemical equations, and mathematical expressions, particularly mathematical equations e.g. the universal gas law, the reaction rate laws.
- The *visual mode*. This makes use of graphs, diagrams, and animations. Two-dimensional representations of chemical structures ('diagrams') are universal examples. Those pseudo three - dimensional representations produced by computers, which may be said to be in the 'virtual mode', also fall into this category.
- The *gestural mode*. This makes use movement by the body or its parts e.g. of ions during electrolysis produced by school pupils moving in counter - flows.

The modes are used in chemistry in three distinct *representational levels* (Gabel, 1994; Johnstone, 1991). These are:

- *The macroscopic level.* This consists of what is seen in that which is studied e.g. a solution of a pure chemical. In such a representation, some aspects of a natural phenomenon have been abstracted or detached from the whole for the purposes of study. Thus: a pure chemical was historically separated from the complex mixture in which it naturally occurs. The macroscopic level is therefore a representation of a chunk of the world-as-experience that science is able to explore conveniently.
- *The sub-microscopic level.* This consists of representations of those entities that are inferred to underlie the macroscopic level, giving rise to the properties that it displays. Thus: molecules and ions are used to explain the properties of pure solutions.
- *The symbolic level.* This consists of any qualitative abstractions used to represent each item at the sub-microscopic level. These abstractions are used as ‘shorthand’ for the entities at the sub-microscopic level and are used to show quantitatively how many of each type of item are present at that level. Thus: chemical equations and the mathematical equations associated with the ‘mole’ concept are used jointly to represent a pure solution.

Being able to work within each of these levels and to mentally switch between them is a vital skill needed for the full appreciation of the explanations that chemistry (and indeed science) provides of natural phenomena. Acquiring this skill presents challenges to many students (Gabel, 1994). This switching between modes involves *visualization*, the making of meaning for each of them. Visualization is concerned with *External Representation*, the systematic and focused public display of information in the visual mode, such as in the form of pictures, diagrams, tables, and the like (Tufte, 1983). It is also concerned with *Internal Representation*, the mental production, storage and use of an image that is often the result of the experience of an external representation. External and internal representations are linked in that their perception uses similar mental processes (Reisberg, 1997).

Visualisation is thus, in the first instance, concerned with the formation of an internal representation from an external representation such that the nature and temporal /spatial relationships between the entities of which it is composed are retained. The attainment of visualization in a particular case can be shown by the production, the expression, of a version of the original for a particular purpose. To be worthwhile, an internal representation must be capable of mental use in the making of predictions about the behaviour of a macro level representation of phenomenon under specific conditions. It is entirely possible that, once a series of internal representations have been visualized, that they are amalgamated / recombined to form a novel internal representation that is capable of external expression: this is the act of creativity.

Visualization is of special importance in three aspects of the learning of chemistry. In:

- *Learning specific consensus or historical chemical models.*
A model that is currently used by a community of scientists in cutting-edge enquiry can be called a *consensus* model. Contemporary examples are: the double-helix model of DNA. A model that once had consensus status but which, although superseded in cutting-edge research, still has explanatory value, is known as an *historical* model (Gilbert, Boulter, & Rutherford, 2000). Historical and consensus models, or those simplified versions that can be called *curriculum* models, are invaluable in science education. First, being the major products of science, ‘learning science’ must involve learning the nature and use of these. Second, because a particular model can be used to provide an acceptable explanation of a wide range of phenomena and specific facts, it is a useful way of reducing, by chunking, the ever-growing factual load of the science curriculum. Visualizing external representations of such models and being able to form internal representations of them are at the core of turning them into knowledge.

- *Learning to develop new qualitative models.*
A major task in the conduct of a scientific enquiry into a hitherto-unexplored phenomenon is the production of a model of it: the process of modelling. Given its importance, all students of chemistry should learn the complex skills of modelling. It has been suggested that these skills can be developed by following the sequence of learning how: to use an established model; to revise an established model; to reconstruct an established model; to construct a model de novo (Justi & Gilbert, 2002a). External and internal representation, together with the associated visualization, is needed at each of these stages.
- *Learning to develop new quantitative models.*
Once chemistry has developed a useable qualitative model of a phenomenon, a quantitative version of it must be produced for a comprehensive representation to be available. Progress in the scientific enquiry into a field is indicated by the value of a particular combination of qualitative and quantitative models in making successful predictions about its properties. Again, visualization is central the production of representations of these models.

Representation – both external and internal - is ubiquitously employed across all aspects of life: the physical, social, and intellectual environments. The associated visualization can be called ‘spatial thinking’ (N.R.C., 2006), p. 28). A fluent performance in visualization has been described as requiring *metavisualization* and involving the ability to acquire, monitor, integrate, and extend, learning from representations (Gilbert, 2005), p. 15). When discussing the relevance of visualization for practice and inquiry in science education, Gilbert (2008) suggested some criteria for the attainment of metavisual status. According to him, a person with a fully-developed metavisual capability should be able to demonstrate: (i) an understanding of the conventions of representation for all the modes of representation; (ii) a capacity to translate a given model between the modes in which it can be depicted; (iii) an ability to construct a representation within any mode for a given purpose; and (iv) an ability to solve novel problems using a model-based approach.

Modelling in chemistry teaching

The dynamic and continuous process of creating, testing, and communicating models – modelling – is of pivotal importance in the growth of scientific knowledge. This is especially true for chemistry, in which the explanations achieved are essentially abstract, for modelling and the use of models enable chemists to visualize entities and processes and hence to think about questions related to them. An authentic chemical education, one that supports the learning of chemical ideas and how chemists’ reason, should thus be based on a recognition of the importance of metavisual modelling skills (Justi & Gilbert, 2002b).

Research Question

In this paper we focus on one research question: How can modelling activities foster students’ acquisition of metavisualization skills?

Research

A Model of Modelling

In a previous paper, Justi and Gilbert proposed a ‘Model of Modelling’ framework (Justi & Gilbert, 2002b) (see Figure 1). It represents a view for how people conduct the process of modelling. The steps that constitute it do not necessarily follow a linear sequence or occur in a unique direction.

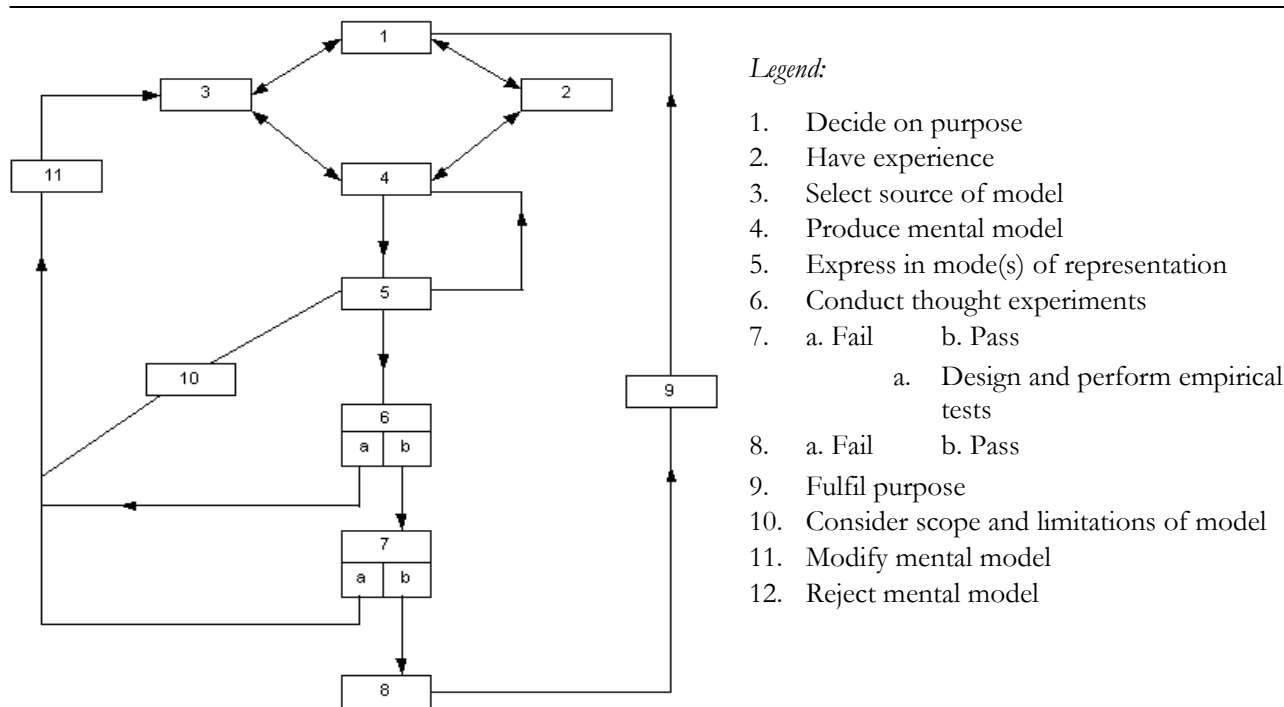


Figure 1. The Model of Modelling framework (Justi & Gilbert, 2002a) (p. 371)

In an attempt to promote modelling-based teaching, some strategies for the teaching of a series of chemical concepts were developed from that framework e.g. in respect of the ionic bond (Justi & Mendonca, 2007).

Data gathering

This study was conducted in a 15-16 years-old Brazilian student class studying ionic bonding, the 32 students working in 6 groups, the teacher for which was extensively experienced in modelling-based teaching.

Data were gathered in 7 classes of 100 minutes in which students were not directly introduced to the modelling framework. Rather, they were provided with conditions for developing each of its stages. The teaching activities are briefly characterised in table 1, which also presents the relationship of each activity to the 'Model of Modelling' (M.M.) framework.

After the research project had been approved by the University of Minas Gerais Ethical Committee, and the students and their parents had signed the authorisations for collecting data in the class and using them for research purposes, all the classes were video-recorded in order to register the discussions occurred between students in each group, between students and the teacher, and the whole-class discussions. We also photographed all the models produced by the students and copied all the written material they produced during the activities.

By integrating all these types of data, we produced case studies for each of the students' groups (Queiroz, 2009). They were discussed by two of the authors (RJ and ASQ) until we reached an agreement about the best way to characterise students' participation in each activity and the development of their metavisualization skills.

Before producing the case studies, we also had developed a series of categories with which to analyse students' acquisition of metavisualization skills (Table 2) (Queiroz, 2009). They were evolve by putting together elements proposed by (Gilbert, 2008), and by (Kosma & Russell, 2005) with some induced from the analysis of our data.

Table 1. Modelling-based teaching approach for ionic bond and its relationship with the M.M. framework (Justi & Mendonça, 2007, p. 3-4).

ACTIVITY	PROBLEM	AIM	RELATIONSHIP WITH THE M.M. FRAMEWORK
1. When is a substance formed?	Burning of a piece of magnesium (macro level) and posing of questions to support the understanding of the transformation (sub-micro level).	To understand how chemical bonds occur in general (with the focus on the relationship between decreasing of energy and increasing of stability of the system).	“Have experience with the target” (by developing or remembering some of the prerequisites needed to the production of the models for the ionic bond).
	Questions related to how some substances are found in nature.	To realise that a substance exists when the energetic conditions are favourable for its production and existence.	
2. A model for the formation of ions	Production of a model for the formation of Na ⁺ and Cl ⁻ ions, from the data for 1st ionisation energies.	To establish relationships between the formation of ions and more comprehensive explanations (sub-micro level) involving energy and attraction forces instead of simply using rules (such as the ‘octet rule’).	“Define the aims” and “Produce a mental model” from the integration of some previous knowledge.
3. How do the ions interact with each other?	Production of a (sub-micro) model for the (macro) system ‘cooking salt dissolved in water’.	To promote the modelling of a known system without asking the students to use the models for the ions produced in the previous activity.	To “produce mental models” and to “express them in any of the modes of representation” ¹ .
	Production of a (sub-micro) model for this same system after the evaporation of the water (macro phenomenon). Justify the model.		
4. Testing the model of the sodium chloride.	To use the model produced in the previous activity to explain the high melting point of sodium chloride.	To realise that the model previously produced can explain empirical data at the sub-micro level. To understand an important property of ionic compounds.	Stage of testing of models (“conduction of thought experiments).
5. Attraction between ions in a lattice.	Production of a new model or changing the previous one using additional data (quantity of energy liberated by the formation of both a Na ⁺ Cl ⁻ pair and a sodium chloride lattice).	To modify the ‘molecule of sodium chloride’ model. To realize the validity of the ‘non molecule’ models (built from several electrostatic attractions making a lattice).	Another test for the models from a new experience with the source that may help in confirming, changing or rejecting the current sodium chloride model.
6. A consensus model for the sodium chloride.	Use of the changed model of sodium chloride to explain its melting temperature.	To give students who had not thought about a more complex ionic structure the opportunity to change their models. To test the new model when trying to understand the melting point at the sub-micro level.	“Conduct thought experiments”. “Consider scope and limitations of the model” (since this activity ends with the agreement around a consensus model for the class).

¹ The teacher should give students several materials like colour pens, play-dough, different sizes polystyrene balls, sticks, etc.

Table 2. Categories of analysis for students' acquisition/use/development of metavisualization skills.

CRITERIA	CATEGORIES OF ANALYSIS
Understanding of the conventions of representation for all modes of representation.	<ol style="list-style-type: none"> 1. To use words to identify and analyse specific aspects of a given representation. 2. To use words to identify and analyse patterns in a given representation. 3. To identify and use conventions for each type of representation: 3D; 2D (graphs, drawings, tables); 1D (chemical symbols, formulae and equations, mathematical equations); verbal (description of entities and relationships between them in a representation, discussion of metaphors and analogies on which the model is based); gestural. 4. To create new conventions of representation.
Capacity to translate a given model between the modes in which it can be depicted.	<ol style="list-style-type: none"> 1. To describe how different representations can express the same meaning. 2. To explain how a given representation can express something different or something that cannot be expressed in another representation. 3. To make connections between different representations in order to both map aspects from one of them into the other and explain the relationships between them. 4. To translate each mode of representation into all the others.
Ability to construct a representation within any mode for a given purpose.	<ol style="list-style-type: none"> 1. To select a given mode of representation and explain why it is adequate for the building of a given model.
Ability to solve novel problems using a model-based approach.	<ol style="list-style-type: none"> 1. To draw a suitable analogy to an already-solved problem. 2. To provide a visual-recall cue. 3. To modify previous representations (by removing irrelevant material or by adding new details) from perceptions of the problem.

In order to discuss the research question, we analysed one of the group case studies by emphasising how each of the actions described in the categories of analysis was fostered in each of the modelling activities, as well as how students had shown them.

Results

In Table 3 we identify the activities in which the students' group displayed the acquisition/use/development of specific metavisual skills. In this table, "A" means that they use the skill in an adequate or coherent way, "P" means that this was partially done, "A/P" means that the group did not behave homogeneously, and "-" means that students did not use a given skill when they were expected to do so. Moreover, boldface lines separate categories for different criteria (according to Table 2).

The analysis of Table 3 shows that the ionic bonding modelling activities do foster the use/development of metavisualization skills. Different characteristics/elements of those activities contributed to that use/development. In Table 4, we identify such characteristics/elements of the activities.

Table 3. How students expressed each of the metavisualization skills in each activity.

CATEGORIES OF ANALYSIS FOR STUDENTS' ACQUISITION/USE/DEVELOPMENT OF METAVISUAL SKILLS	ACTIVITIES					
	1	2	3	4	5	6
To use words to identify and analyse specific aspects of a given representation.			A	A		A
To use words to identify and analyse patterns in a given representation.		A				
To identify and use conventions for 3D representations.			P	A		
To identify and use conventions for 2D representations (graphs).			–			
To identify and use conventions for 2D representations (drawings).			P	A/P	A/P	
To identify and use conventions for 2D representations (tables).		A				A
To identify and use conventions for symbolic representations (chemical symbols).	A		A			A
To identify and use conventions for symbolic representations (chemical formulae).	A					A
To identify and use conventions for symbolic representations (chemical equations).	A					A
To identify and use conventions for symbolic representations (mathematical equations).		A				
To describe entities and relationships between them in a representation.			A/P	A	A	
To discuss metaphors and analogies on which the model is based.	A/P		A/P	A	A	A/P
To identify and use conventions for gestural representations.						
To create new conventions of representation.						P
To describe how different representations can express the same meaning and to explain how a given representation can express something different or something that cannot be expressed in another representation.		A/P	P			
To make connections between different representations in order to both map aspects from one of them into the other and explain the relationships between them.			P	A		A
To translate 3D into 2D (drawings).			A	A		
To translate 3D into symbolic.			A	A		
To translate 3D into oral/written description of entities.			A	A		
To translate 3D into oral/written discussion of metaphors and analogies.						
To translate 3D into gestural.			A	A	P	
To translate graphs into mathematical equations.						
To translate drawings into chemical formulae.				A	A	
To translate drawings into chemical equations.						
To translate drawings into oral/written description of entities.				A	A	
To translate drawings into oral/written discussion of analogies.						
To translate tables into mathematical equations.		A				A
To translate tables into oral/written description of entities.		A				
To translate tables into oral/written discussion of analogies.		A				
To translate drawings into gestural mode of representation.						
To translate chemical symbols into oral/written description of entities.	A	A	A			A
To translate chemical formulae into oral/written description of entities.	A					
To translate chemical equations into oral/written description of entities.	A					A
To translate mathematical equations into oral/written description of entities.		A				A

Table 3. (Continued)

CATEGORIES OF ANALYSIS FOR STUDENTS' ACQUISITION/USE/DEVELOPMENT OF METAVISUAL SKILLS	ACTIVITIES					
	1	2	3	4	5	6
To translate chemical symbols into oral/written discussion of metaphors and analogies.						
To translate chemical formulae into oral/written discussion of metaphors and analogies.						
To translate chemical equations into oral/written discussion of metaphors and analogies.						
To translate mathematical equations into oral/written discussion of metaphors and analogies.						
To translate symbolic into gestural representations.						
To translate oral/written description of entities into gestural.					A	A P
To translate oral/written discussion of metaphors and analogies.						
To select a given mode of representation and explain why it is adequate to build a given model.	A/P	A	A/P	A	A	A
To draw a suitable analogy to an already-solved problem.		A/P	P			A
To provide a visual-recall cue.					P	A A A
To modify previous representations (by removing irrelevant material or by adding new details) from perceptions of the problem.					A	A A

Table 4. Characteristics/elements of the teaching activities that contribute to use/development of metavisualization skills.

Criteria for the attainment of metavisual status	Characteristics/elements of the teaching activities. An address to:
Understanding of the conventions of representation for all modes of representation.	<ol style="list-style-type: none"> 1. Questions about a phenomenon (macro level) that were explained using the symbolic mode of representation. (Act. 1) 2. Questions that require the interpretation of data organised in a table. (Act. 2) 3. Questions that ask for justifications for decisions about the modes of representation. (Act. 3, 5) 4. Questions that ask for the production of a model (Act. 2, 3) 5. Questions that ask for testing and revising a model (Act. 4, 5, 6) 6. Questions that ask for explicit comparisons between two models. (Act. 4, 5, 6)
Capacity to translate a given model between the modes in which it can be depicted.	<ol style="list-style-type: none"> 1. Questions that ask for specific translations. (Act. 3, 4, 5) 2. Presentation of the groups' ideas or models to the whole class. (Act. 1, 2, 3, 4, 5, 6)
Ability to construct a representation within any mode for a given purpose.	<ol style="list-style-type: none"> 1. Questions in which students are free to select the mode of representation to be used in their answers. (Act. 1) 2. Questions that require the production of a model (Act. 2, 3) 3. Questions that ask for justifications for decisions about the modes of representation. (Act. 3, 5) 4. Questions that ask for testing and revising a model (Act. 4, 5)
Ability to solve novel problems using a model-based approach.	<ol style="list-style-type: none"> 1. Questions involving new situations that can be solved by analogical reasoning. (Act. 2, 3, 6) 2. Questions involving new situations that can be solved by using previous models. (Act. 3, 4, 5, 6)

Conclusions and Implications

Support for the acquisition of metavisual capability in respect of internal representations in the classroom is a badly neglected field of development/research. It would seem to involve providing students with ample opportunities to both develop internal representations and to express them as external representations. It can be done by modelling-based teaching. The sequence of six activities within the 'Model of Modelling' framework provided an effective approach to the 'teaching of the ionic bond', the evidence for which is provided elsewhere (Justi & Mendonca, 2007). Participation in the modelling activities certainly seemed to support the students' use/development of most of the skills related to metavisual capability. This may have occurred due to the several opportunities to both develop internal representations and to express them as external representations that were provided by the modelling activities. However, the data suggests that, in order to be able to demonstrate full metavisual capability within this context, some students need more experience in: drawing upon existing models and using them as analogies, and in the construction of new representations.

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CASE STUDIES OF STUDENTS' VISUALIZATION OF SCIENCE – A DUAL CODING PERSPECTIVE

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Abstract

This paper starts by elaborating dual coding theory (Paivio, 1986), highlighting the uses and connections of verbal and visual representations in information processing. The specialized functions of visual representation, as compared with that of the verbal, are addressed. The theory is then used to re-conceptualize the notion of 'visualization'. Based on this, an empirical study of students' visualization of two science topics (electrostatics and washing/ emulsification) is reported. It illustrates what dual coding theory can offer to our knowledge of students' visualization of science. This includes the suggestion of a novel method of eliciting students' understanding of science; and some new findings and interpretations of students' understanding based on the method.

Background

The notion of visualization emphasizes the role of visual mode of representation in the learning, making meaning and the development of science (Gilbert, 2008). Through dual coding theory (Paivio, 1986), which developed from cognitive psychological research, this study investigates a way students understand science concepts. The crux of the theory relevant to this paper is that there are two independent but interconnected functional systems, namely the verbal and nonverbal system, for the processing of information. The two systems are represented in **Figure 3** as a big rectangle and a round rectangle respectively.

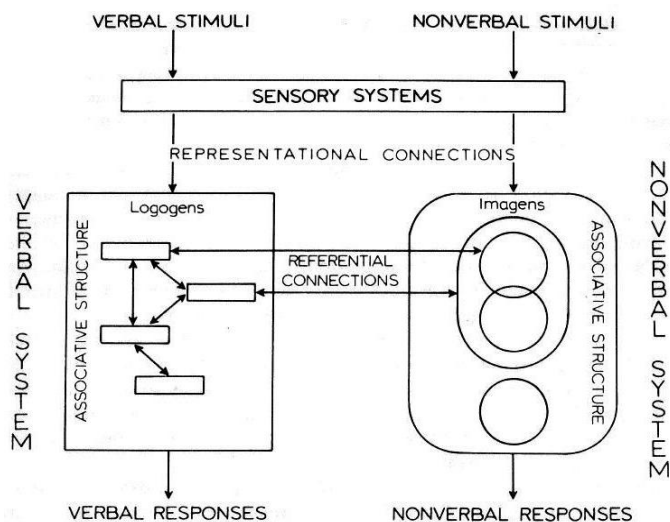


Figure 3. A representation of dual-coding information processing model (Paivio, 1986, p.67).

Basic tenets of dual coding theory – the connections:

Information processing implicates making different levels of connections (*ibid.* p.67). They are:

- (i) Representation connection – It refers to the connections between external stimuli with verbal and/or nonverbal systems. They are represented by the single-head arrows linking the ‘sensory system’ and the ‘verbal system’, and the ‘nonverbal system’.

For example, when the written word ‘apple’ is registered in the sensory system and is recognized, it is said that a person is making representational connections between the written word and the verbal system. Similarly, when a photograph of ‘apple’ is registered in the sensory system and is recognized, it is said that a person is making representational connections between the photograph and the nonverbal system¹.

- (ii) Referential connection – It refers to the connections between elements across systems, i.e. a word and its corresponding image, and vice versa. Such connections are represented by the two double arrows joining the verbal and nonverbal system in **Figure 3**.

When we form a visual representation of an apple based on the word ‘apple’ registered in our verbal system, it can be said that a referential connection is formed between the word ‘apple’ and its image. Similarly, when we mentally name an image, e.g. an apple, a referential connection is formed.

- (iii) Associative connections – It refers to the connections between elements within the verbal system or non-verbal system.

Based on the ‘apple’ in our verbal system, we may be able to generate a list of words in relation to it, e.g. ‘fruit’, ‘plant’, ‘healthy’, or even a ‘snake’. This process is about making associative connections between words; and is represented by some double arrows linking up the small rectangles in **Figure 3**.

Similarly, based on the ‘apple’ in our nonverbal system, we may be able to generate visual representations of it in different perspectives, and how it looks like when this is cut into two halves. When this happens, it is said that we are making associative connections based on the image ‘apple’. This is represented by overlapping circles and subsuming circles inside an oval in **Figure 3**.

According to dual coding theory, information can be recalled and manipulated more easily if it is coded or processed in both verbal and nonverbal system. In another word, there is referential connection between the verbal and nonverbal mode of representation. Such idea is coherent to the differentiation of rote learning from meaningful learning in which the latter refers to the learning when concepts are connected rather than isolated (Ausubel, 1968). In view of the dual coding theory and Ausubelian view of learning, the study will investigate how students would make: (i) referential connections across the verbal and nonverbal system; and (ii) associative connections between visual representations within the nonverbal system.

Dual coding theory and the notion of visualization:

Very often, we would have to learn and develop scientific models through different perspectives (cross- and longitudinal-section; the left-right reversion in human physiological drawings), dimensions (2D and 3D), and levels of representations (macro and submicro) etc. Also, we must be able to link up these visual representations with verbal information. Indeed, the capability to make referential connections is not limited to the learning of school science, but also in the construction of meanings in professional scientific journals and advanced texts (Lemke, 1998).

Based on dual coding theory of information processing, it is now possible to define ‘visualization’. In this paper, the notion ‘visualization’ refers to the process of forming internal representation of a physical phenomenon,

¹ According to the dual coding theory, the nonverbal system includes the visual system, auditory system (hearing), olfactory system (smelling) and haptic system (feeling of touch) etc. In this study, we will only focus on the ‘visual system’. Unless otherwise stated, whenever ‘nonverbal system’ is mentioned, it refers to the ‘visual system’.

event, object, process or a system. In this sense, the idea of visualization is compatible with that of ‘mental modelling’ (Gilbert, 2004), i.e. a process involves the formation and manipulation of ‘a private and personal representation formed by an individual either alone or in a group’ (p.117). While a mental model may take various forms, visualization is a process which invokes the specialized use of visual representations. Using the ideas of dual coding theory, we are able to conceptualize ‘visualization’ more specifically. Rather than merely evoking a visual representation, visualization should also include:

- * Making referential connections between verbal mode and visual mode i.e. formation and/or manipulation of a visual representation based on a word or a list of words;
- * Making associative connections between various visual modes of representations. From the above discussion, there are many different types of associative connections, namely, the linking of and among different perspectives, dimensions and levels of representation etc.

In this study, we would investigate the way students visualize (i.e. making referential and associative connections) selected school science topics. Through empirical study, i.e. interviewing students, their visual representations of the selected science topics would be inferred. Rather than focusing on reporting alternative conceptions, we would like to highlight the challenges that students might face in the meaning making from external visual representations.

Methodology

Students’ understanding of topics which made explicit use of both visual and verbal modes of representation will be investigated. They are (i) electromagnetism and the working of electric motor, (ii) electrostatics (both GCSE physics equivalence); (iii) structure, bonding and properties of metal, (iv) washing by detergent through emulsification (both GCSE chemistry); (v) the structures of human ears and hearing mechanism (A2 level biology) and (vi) human circulatory system (GCSE biology equivalence). Informed by the dual coding theory, students understanding will be elicited through the use of visual representations particularly.

Students were interviewed after they had been taught the corresponding topic. In general, they will be asked to express their understanding of the corresponding topic verbally, followed by the request to represent their understanding through drawing diagrams and verbal explanation. Through this, students’ making of referential connections of the science idea is probed. Then, students were presented with diagrams used by their teachers or by the textbooks (the exemplars). They were asked to compare their own drawings and the presented exemplars. Through their comparison, their making of associative connections between visual representations is inferred.

Seventy-two students from twelve classes were interviewed; six students from each class whom represented the highest, middle and lowest achieving in the corresponding subject were selected. Each interview lasted for 20-40 minutes. As there was a need to capture students’ elaboration of diagrams along their deictic gestures, all interviews were video recorded, with the camera focusing on the drawings/diagrams under discussion. The video data were reduced through multimodal transcription (Plowman & Stephen, 2008). Students’ articulations of their understanding, through verbal and/or visual modes, were analyzed based on the different levels of connection proposed by dual coding theory. In this paper, we will only report our findings from the study of two topics: electrostatics and washing by detergent through emulsification. They are selected because it is believed that they can illustrate some of the key ideas of dual coding theory (e.g. imagens, referential connections and associative connections) within the scope of a paper.

Results and Discussions

In this section, data from two science topics will be presented. The data are presented along with the relevant literature (where there is) about students’ understanding of the corresponding topics. In section 0, students’

understanding of electrostatics through their own drawings will be presented. This way students make referential connections across visual and verbal representations will be discussed. In section 0, students' understanding of the mechanism of washing by detergent (through emulsification), which was probed through their own drawings and their interpretation of relationships between different visual representations, will be presented. This way students make associative connections between visual representations will be discussed.

Understanding electrostatics: Visual representations and referential connection

Guruswamy, Somers and Hussey (1997) investigated students understanding of the transfer of charges between conductors. The students were asked to decide the final charge of conductors which initially bore different charges respectively and were then brought into contact. In the tasks, students were asked to represent the resultant charges of the conductors by numbers. Although the task also demanded students to draw the distribution of the charges, the paper did not explain why this was done nor elaborate what was found based on students' drawings. The interpretations of students' responses were reproduced in .

Also, it was found that some students ranged from grade eight to advanced college level went about similar task based on rule that "There is no transfer of charge between two conductors with charges of the same sign '(p.95).

Table 1. Guruswamy *et al's* interpretation of students' responses to the task probing into the understanding of transfer of charges (1997, p.94).

Student devised rule	Typical student diagram
Transfer between the two identical metal objects occurs until each object has half the initial net charge. (Correct response)	
Transfer between two oppositely charged metal objects occurs until one of the objects is neutral.	
There is no transfer between a charged metal object and a neutral metal object.	

In our study, we develop a task based on Guruswamy *et al* (1997). We asked students to draw exactly the number of charges on each conductor and how the charges distributed over the space of the spheres (see Table 2). We particularly did this because we would like to make specific use of the visual representation in which spatial distribution and relationship between entities – in this case, the charges – can be represented more accurately. While some of our data and findings replicate the earlier study (not going to be in this paper), there are novel findings. It is believed that such findings are a direct consequence of making explicit use of visual representation in probing students understanding.

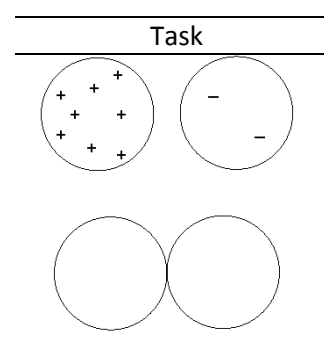
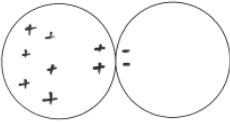
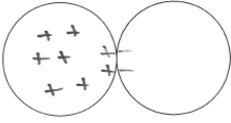
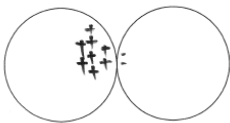


Table 2

One-to-one attraction:

Although students fluently stated 'Same charges repel and different charges attract' in various occasions during the interviews, it seems they have different applications and interpretations out of the statement when they were asked to complete the task as shown in Table 2. Table 3 show students' drawings from the task given:

Table 3

Student H1' drawing	Student M2' drawing	Student L2' drawing
		

This is apparent in the drawing of H1 and M2 (see Table 3) that the two negative charges are squarely attracted to/by two positive charges. While the attraction of negative charges towards the positive charges in L2 is not apparent from the drawing, the students indicated in the interview that: “Two negative charges, attract two positive charges. Other positive charges will try to compete for the two negative charges, so they stay behind.” [L150, L2]

While students hold the idea ‘Same charges repel and different charges attract’ – as verified from their verbal responses during the interviews – they might have qualified the statement ‘different charges attract’ as ‘one positive charge attracts one and only one negative charge’ or ‘one negative charge attracts one and only one positive charge’. Those residual positive charges become irrelevant despite of the verbal thumb rule and the Coulombic electrostatics. Indeed, such one-to-one attract conception is not unlike the finding that some students believed one electron is attracted to one proton in the nucleus of a sodium atom (Taber, 2002).

In the investigation of students’ understanding of ionic bonding, Taber (1997, 1998a) reported many students hold the idea that one cation is attracted to only one anion in an ionic lattice-one-to-one attraction; and that the pairing is done by the process of electron transfer. In a true-false exercise, half of the students (n=370) agreed that ‘... a sodium ion is attracted to one chloride ion by a bond and is attracted to other chloride ions just by forces’ (p.90, 1997). While students’ responses were revealing, the question was set in the assumption that students would notice there is some kind of forces between the sodium ion and the ‘other chloride ions’ (be it called ionic bond or ‘just forces’). In our study, however, this is found that while students can declare the statement ‘different charges attract’, they did not necessarily share the view that opposite charges not in close proximity also have force of attraction. That is, the question could have been rephrased as “... a sodium ion is attracted to one chloride ion by a bond and is not attracted to other chloride ions”.

Based on the students’ visual representations, we are able to explore their conception of electrostatics at another context, which is at a more general and fundamental level than the understanding of chemical bonding, the interaction of electrons-protons in an atom and the concepts associated with ionization. From our data, it seems that students’ difficulties in understanding those fundamental chemistry concepts stem not only from “I can’t think about physics in chemistry” (Taber, 1998b), but also from their difficulties in visualizing fundamental physics, i.e. the interaction of positive and negative charges. It is suggested that the insights of findings and interpretation reported here is a direct result of making explicit use of students’ drawings and their verbal explanation, i.e. the probing of referential connections between the visual and the verbal.

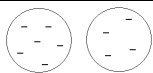
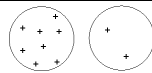


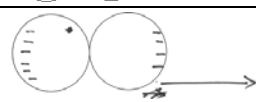
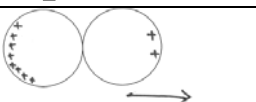


“Different charges attract; but same charges don’t quite repel”:

There are two key messages embedded in the statement ‘Same charges repel and different charges attract’, i.e. the two conditions under which charge particles would repel and attract. From students’ drawings, it is noticeable that students’ focuses have been overwhelmingly on the attraction of positive and negative charges (see the proximity of positive and negative charges in the drawings of Table 3). Despite of the statement ‘same charges repel’, the repulsion between positive charges were barely represented. This is especially prominent in the drawing of L2 in which all the positive charges aggregate in the very limited area and, according to the student, they ‘try to compete for the two negative charges’. In another words, attraction overweighs repulsion.

The neglect of repulsion is also evident in another task in which students were asked to represent the distribution of charges when two conducting spheres bearing the same charge were brought together. The drawings of two students are reproduced in

Table 4:

Table 4

Task		
		
Student M1' drawing		
Student L1' drawing		

The same as previous findings, there is no transfer of charge between two conductors with charges of the same sign (Guruswamy, et al., 1997). Nevertheless, students predicted that the conducting spheres would repel. This was represented by their use of arrows and their verbal message during the interview. As far as the two metal spheres were treated as two single entities which bear the same charges, the visual representation (the use of arrows) is coherent to the verbal statement 'same charges repel'. However, the visual representation is at odd with the verbal statement when we consider the charges within individual spheres. Within the individual spheres, based on the distance between the same charges, not only the same charges don't quite repel, they were drawn so closed that the separation of the charges is similar to those between opposite charges of Table 3. That is to say, the same charges do not quite repel in these visual representations. In another words, no referential connection is made across the verbal representation (the statement that 'same charges repel') and the visual representation.

Understanding washing: visual representations and associative connections

It has been established that understanding chemistry involves meaning makings of macro, submicro and symbolic levels of representations (Johnstone, 1993). In many senior secondary school chemistry curriculae, students are (arguably) expected to be able comprehend and connect these three levels. Perhaps not unexpectedly, many students find it challenging to understand one of these levels, linking two of these levels (i.e. macro-submicro, submicro-symbolic and macro-symbolic), and/or connecting these three levels; or in short, the visualization of these levels of representations (see Gilbert & Treagust, 2009 for detailed discussions of these issues). A further complication to these levels is that they are physically represented at different dimensions (Gilbert, 2008). When they are expressed as 3D or 2D, they fit squarely with the visual mode of representation according to dual coding theory. It is suggested that making meaning from the any or all of the above-mentioned relationships involves the making of associative connections between visual representational.

There have been many studies that explored students' understanding of physical changes and chemical reactions (see Kind, 2004 for a review). While some of the studies target at chemical reaction/change at a very general level (Andersson, 1986), some others investigate a particular class of chemical reaction, such as precipitation reaction (Smith & Metz, 1996), acid-base reaction (Sheppard, 2006) and combustion (Watson, Prieto, & Dillon, 1997). In this study, we will investigate washing of grease by detergent, through the process of emulsification. This is a kind of changes that is very common to students' daily experience; yet which has never been studied.

An understanding of the mechanism entails the verbal description of the emulsifying action of the hydrophilic head and hydrophobic tail of detergent molecules, which leads to the formation of micelles (oil droplets in school chemistry terminology). It also entails visualizing the relationship between macro phenomena (3D and 2D) and the submicro representations (2D, see **Figure 4**).



Figure 4. A submicro representation of emulsification.

In this study, we will particularly investigate students' interpretation and understanding of 2D representation at macro and submicro levels. While doing this, the relationships between visual and verbal representation (i.e. referential connection) will also be examined.

Making referential connections between verbal and visual representation:

In general, students were able to express how washing of grease by detergent is done by emulsification. Their responses are typically:

Because there is hydrophilic head and hydrophobic tail. Then the hydrophilic head dissolves in water, er, the hydrophobic dissolves in oil. Then, after this [referring to detergent] is added, it makes them mutually dissolved. Because, it forms, it would, it forms oil droplets. Then it would, er, because those hydrophilic heads outside bear negative charge. They wouldn't dissolve together, so it would clear the grease. [Ko Yan 1, line 14]

When the student was asked to represent the verbal message in the form of diagram, the student produced a diagram (Figure 5) shown similar to Figure 4, in the sense that the right drawing involved (i) the partition of the hydrophobic tails of detergent molecules to the oil drop, and that (ii) the oil drop subsequently broke down, represented by the arrow, into smaller droplets. Notably, the student was able to make coherent linkages between the verbal messages and drawing.

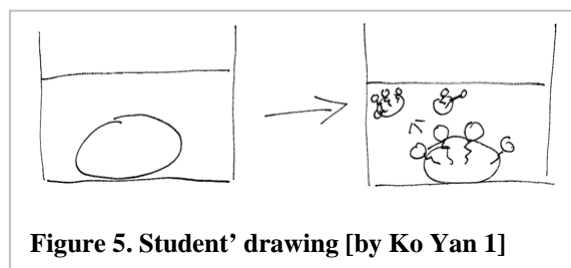


Figure 5. Student's drawing [by Ko Yan 1]

Indeed, such capability was common across the students. In terms of dual coding theory, students are able to make referential connections between verbal and visual modes of representations. These findings seemingly make a stark contrast with the current literature about students' understanding of chemical and physical changes. In the following subsections, we will discuss some probes that go beyond a one-to-one referential connection of the two representational systems. Some findings based on these probes will be discussed.

On visualizing scale: making associative connections between visual representations:

A meaningful understanding of emulsification/ washing involves making meanings between the macro phenomena (washing, or miscibility of oil and water with the action of detergent) and submicro level. After ascertaining their submicro representations – via verbal and visual modes – the students were presented Figure 6. All students in our interview could accurately interpret the macro phenomenon in which oil and water became miscible after shaking with detergent. To probe their understanding of the relationship between the macro phenomenon and the submicro representation, they were asked (a) what they would see if they

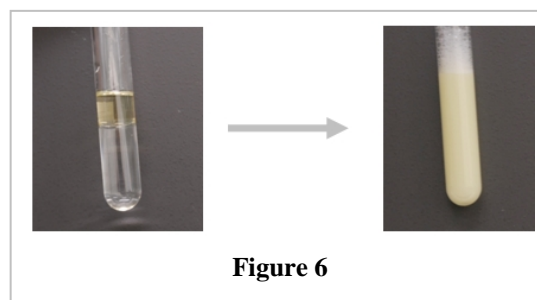
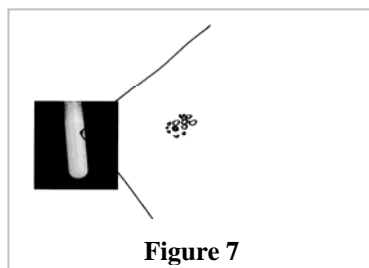


Figure 6

magnify a particular part of the test tube, and (b) the relationship between the test tube and the diagrams they have drawn. To investigate how far they have magnified in their drawing, they were asked (c) the size and the location of water molecules. In this section, we will report a case study based on the drawings of a student.

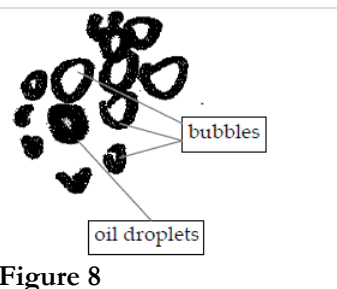
A case study

While the student <Ko Yan 1> demonstrated the referential connections of emulsification/ washing, she expressed that there would be bubbles and oil droplets when the solution was magnified (see **Figure 7** for her drawing):

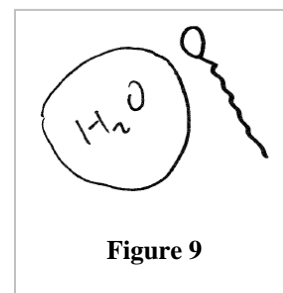


When further probed the meaning of the drawing and where the water has gone to, the student proposed a very detailed structure:

... If this is oil droplet (while pointing to the central dot, see Figure 8), there are some bubbles around it (while drawing some small circles around the solid dot), they are smaller, not separable. This is the oil droplet (while pointing to the central circle), these are bubbles (while pointing to the surrounding circles, see Figure 8 for the result of her pointing). [Line 52] ... The bubbles must be detergent... [Line 56]



Based on her drawings from **Figure 7** and **Figure 8**, it is suggested that the student has reproduced the macro phenomenon (emulsion) based on its observable and perceptible features (oil droplets and bubbles), i.e. at the macro level again. In another words, when the student was asked to magnify based on the emulsion, the extent of magnification has yet to reach the submicro level. Following this, this is argued that the student was not able to meaningfully link up the macro representation (i.e. the test tube of emulsion) with the submicro representations (i.e. her own drawing, or textbook diagram as illustrated in **Figure 4**). Other than the difficulties of scaling up and down of the macro and submicro, the student also find it difficult to visualize the relative size of water and detergent molecules (see her drawing that represents the relative size of the molecules in **Figure 9**). In this case, the student has failed to visualize the relative scale of chemical species at a submicro level.



Based on the drawings of the student, it is suggested that making meaningful associative connections within the visual system of representation, i.e., those between visual and visual representations a big challenge to students. In short, there are difficulties in: zooming in the macro phenomena and visualizing submicro representation; and drawing appropriate scaling of chemical species.

Interpretation of students' drawings based on dual coding theory:

In the previous section, the idea of 'associative connection' (linkages within the visual representational system) has been used to interpret students' drawings. It addresses students' connections between 2D macro phenomena and 2D submicro representations. Nevertheless, it should be noted that the idea of associative connection is not limited to the macro (the emulsion) and submicro (micelles).

Even within the submicro level, successful visualization involves the capability to spatially connect different fundamental element into larger images. When doing this, the relative size and scale of those fundamental elements have to be properly visualized. In the context of this topic, within the submicro level, students would have to visualize: (i) the chemical structural formula of detergent molecule as a symbol (fundamental imagen) made up a circle and a zigzag tail; (ii) the micelle (larger images) as an oil droplet with the partition of many hydrophobic tails of detergent molecules in it – spatial distribution of detergent molecules in oil droplets; (iii) many water molecules are around those micelles – spatial distribution of micelles and water molecules.

From our data, visualizing (1) and (2) did not seem to be challenging to students (only that students may not link (1) and (2) with the macro phenomena). It is suggested from the data that students did not spatially relate water molecules and micelles properly; hence visualizing (3) became a challenge.

Conclusions and Implications

Although dual coding theory has been cited in some science literature, at best, they simply touched on the ideas that there are verbal and visual representational systems and that recalling and processing of information is better when both of them are utilized. This paper attempts to give a more detailed account of the theory; and suggests how it can be relevant and indicative to our knowledge of students' making of meaning from visual representations in learning science. Grounded in cognitive psychology research, the theory re-conceptualizes the notion of visualization. It can be defined as the capability in making one or both of the followings:

- (i) Referential connections of representational units across the verbal and visual system, i.e. connections between logogens and imagens;
- (ii) Associative connections between visual representations within the visual system, i.e. connections between imagens.

In the context of science education, associative connections can be more specifically regarded as the making of connections between different perspectives (cross- and longitudinal-section; the left-right reversion in human physiological drawings), dimensions (2D and 3D), and levels of representations (macro and submicro) of scientific models. Being fluent in visualization means that one can see through any of all of the above connections as is required in particular contexts.

This study is undertaken based on the above framework of visualization. Students' visualization of two topics, namely electrostatics and the mechanism of emulsification in washing, were investigated. Informed by the ideas of referential and associative connections, we interpreted how students linked:

- (i) verbal representation and visual representations. This was achieved through: a comparison of their verbal message and their own drawings, and an analysis of how they described or explained those exemplar 2D representations, i.e. those from their textbook or those presented by their teachers.
- (ii) different visual representations. This was done through an analysis of how they related: their own drawings with exemplar 2D representations, and different exemplar 2D representation.

The rationale behind the probing and data analysis can be represented in the following figure 8.

The results so presented aim at illustrating how different aspects of dual coding theory can be applied in enriching our knowledge of students' visualization of science. From the study of electrostatics, it is observed that while students could state a principle of Columbic electrostatics, their visual representations revealed various qualifications of the verbal statement. For example, the statement 'opposite charges attract' was illustrated as merely 'one-to-one attraction'. That is, a positive charge is only attracted to one and only one negative charge, and vice

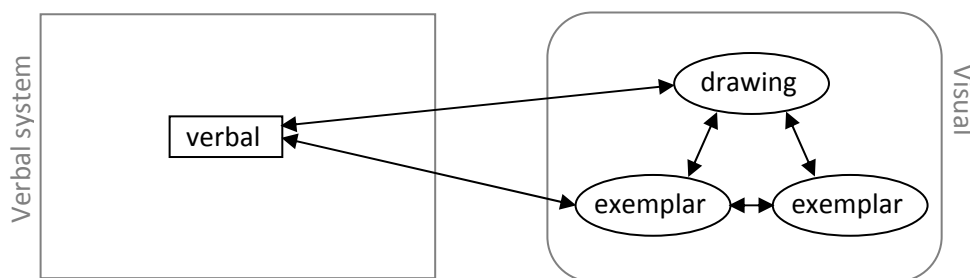


Figure 10. The arrows linking across 'verbal' and 'drawing'/'exemplar' represents students' making of referential connections. Those arrows within the visual system refer to associative connections.

versa (Table 3). In another word, students making of referential connections between verbal and visual representation is problematic. This is suggested that, as a result of collecting data via dual representations, not only the finding was novel to literature (c.w. Guruswamy, et al., 1997), but also that the interpretation offer an overarching explanation of students' alternative conceptions about some fundamental chemical concepts, namely chemical bonding, the interaction of electrons-protons in an atom and the concepts associated with ionization of atoms.

Also, while students focused on the macro behaviour of charged conducting spheres (the larger image), they might have neglected the submicro behaviour of charged particles (the fundamental elements). This was demonstrated in their visual representation in which particles of the same charge did not seem to repel – another instance of the incoherence of verbal and visual representation.

The cases of electrostatics in exploring students' making of referential connections are complemented by the cases of emulsification, which delved into associative connections. While students seemed to be able to link the verbal and visual representations of the process of emulsification at submicro level, their challenges lied at visualization washing-as-a-macro-phenomena at that submicro level (that they could recall!). A case was reported in which the student' visual representation might have been a blend of the submicro (exemplar diagram) and the macro (see Figure 8). It seems plausible that some students might not be aware of the use of submicro in making sense of macro phenomena in chemistry. What emerged from the cases in general was that many students did not properly visualize the scale of water and detergent molecules. That is, the zooming-in (a specialization of visual representation) of the macro phenomenon was not well-utilized. In short, these findings suggest that the making of associative connections between visual representations at macro and submicro (not macro and macro), and between chemical species of different size are challenging to students.

Traditionally, many studies of students' conceptions of science have had a focus on the verbal representation. While this has been useful, these studies might have failed to delve into another half chunk of representational system. Dual coding does offer a comprehensive tool. This is hoped that the study of the two topics has explicated (i) the meaning of visualizations (making of referential and associative connections), (ii) the strategies to explore students' visualizations, and (iii) the likeliness of dual coding theory in offering novel findings and new insights of students' visualizations.

Other than the theoretical advancement (a synthesis of the research in science education and cognitive psychology), this is believed that the strategy developed based on the theory (see Figure 10) can also be transferred to the study of other science topics. Given a large variety of 2D visual representations used in textbooks and web pages, further studies can be conducted to explore an exhaustive list of 'associative connections'. In terms of classroom teaching, this study demonstrates some challenges students may face in visualizing science, and hence pose a question about the kind of learning experience students would need in order that they can develop the skill to visualize. In terms of assessment, the study poses challenges to the validity of verbal based assessment instrument, and urges for the inclusion of visualization in authentic assessment.

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RECOGNIZING THE STRUCTURAL ROLE OF MATHEMATICS IN PHYSICAL THOUGHT

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Abstract

Physics and Mathematics have been deeply interrelated since the very beginning of scientific knowledge and this mutual influence has played an essential role on both their developments. Historical case studies show us both physical problems motivating the creation of mathematical concepts as well as mathematics previously originated in the “abstract world” being used and physically interpreted. However, in the context of education, these two disciplines tend to be treated separately and the students hardly become aware of this successful interplay. In this paper, we propose a categorization that aims at identifying philosophical conceptions and beliefs present in the discourse of physics students and teachers. Considering the cognitive dimension, we propose a distinction between technical skills – the ones related to the domain of basic rules of mathematics and normally developed in math’s classes – and structural skills – which are related to the capacity of employing the mathematical knowledge for structuring physical situations and recognizing their interrelations. Some classrooms observations have been made in order to identify how professional physicists use mathematics to structure their thought and to verify whether or not they explicitly mention these interrelations to the students.

Introduction

Mathematics, from the Greek word *mathema* (μάθημα) – which can be translated as “something that has been learned or understood” or “learnable knowledge” (BOCHNER, 1981, pp. 24) – is generally related to the search for patterns, rigor, truth and beauty, and its evolution can be considered as an ever-increasing series of abstractions. Physics, from the Greek term *physis* (φύσις), which means “nature”, is normally associated to the comprehension of natural phenomena and to the pursuit of the very basic laws of the universe. Would it be possible to infer that the former deals with an abstract world created by our own mind, while the latter is concerned with the physical/concrete and “real” world? A brief look on the historical development of these branches of knowledge immediately eliminates this naïve interpretation by becoming evident the deep interrelations existing between them since the very essence of scientific knowledge.

This brief look allows us to realize that several mathematical concepts have its origin in genuine physical problems. Just to mention a few examples: Einstein (1921) considered geometry to be one of the oldest physical theories; the origin of calculus is practically inseparable from the description of movement so that in Newton’s theory of fluxions, the fluent variable was the time and the fluxion the instantaneous velocity (Boyer, 1949); according to Poincaré (1970), differential equations were originated in the core of physics to solve physics’ problems; vector algebra/analysis is directly related to the mathematization of electromagnetism (Silva, 2007); Fourier analysis was motivated by problems of waves in strings and propagation of heat (Davis and Hersh, 1981), amongst many others.

In an inverted reasoning, mathematical concepts created in an “abstract world”, without any compromise with applications to the “real world”, are commonly “used” by physicists to construct their theoretical explanations of phenomena. Some philosophers use the analogy of *prefabricated mathematics* and compare the physicist’s attitude to “a person who goes to the market of mathematics to take what he needs to construct his theory” (BONIOLO and BUDINICH, 2005, pp. 83). This is actually the case for the conic sections, initially studied by Apollonius of Perga in the III century B.C. and used almost two thousands years later by Kepler to describe the movement of the planets. Another interesting episode is the rising and development of the complex numbers in the XVI century, motivated by the intern mathematical problem of finding solutions for cubic equations, and two hundred years later, these “imaginary” numbers were being used and physically interpreted initially in the optics of Fresnel, and afterwards in electrodynamics and quantum mechanics (Bochner, 1981). More recently, other examples of prefabricated mathematics are found in the application of non-euclidean geometry and tensorial calculus in general relativity and the use of Hilbert space in quantum mechanics.

These remarkable historical relations between mathematics and physics can (and should) be made explicit in the context of science education. Unfortunately, what we find in regular classrooms in Brazil is far away from that goal. Recent studies on Brazilian students’ scientific conceptions (Karam, 2007; Ricardo and Freire, 2007) show us that they hardly recognize the structural role of mathematics in physical thought and don’t realize the importance of physics for the development of mathematical concepts. Our main verifications are that: i) Students lack understanding of the conceptual meaning of physics’ equations; ii) In physics’ classes, mathematics is normally regarded as a mere tool to solve problems; iii) In math’s classes, physics tend to be only an application of previously defined mathematical abstract concepts; iv) Many mathematical concepts are learned without any relation to the physical problems that originated them; v) No integrated curricula is implemented or even discussed; and vi) Students memorize equations instead of deriving them from physical principles.

From what has been seen in the international literature, it is possible to infer that similar problems are found world wide. Defending the importance of modeling for physics’ education, Angell and others (2008) argue that the understanding of the physical description of phenomena involves the ability of representing these phenomena through multiple representations and being able to translate between them. One of the conclusions of their research is that translating from physical situations to the formalized language of mathematics is the most difficult task for students. A similar result was obtained by Tuminaro and Redish (2007) when they analyzed and categorized the students’ use of mathematics when solving physics’ problems. The theoretical framework proposed by the authors consists of six hierarchical structures (Epistemic Games), which allow them to understand students’ reasoning when solving physics’ problems. The most intellectually complex e-game is called Mapping Meaning to Mathematics and it involves the ability of translating the conceptual physical story into mathematical entities and relating them to the same story. This was recognizably the most difficult task for the students of the research.

Aiming at facing up to this challenge, we propose a distinction between *technical* and *structural skills* when it comes to analyzing the students’ use of mathematics in physics and the comprehension of their interdependence. In this paper, we describe a set of five structural skills and argue that they should be aimed at in physics (and mathematics) education. Taking into account that mathematics has a structural role in physical thought (Pietrocola, 2008), these skills were inspired both by epistemological and empirical studies. Some classrooms observations were made in order to verify how a particular professional physicist/professor approaches this structural role in his lessons. Three teaching episodes, extracted from the recordings of these lessons, are described and analyzed.

Rationale

One of the main concerns of physics teachers, whichever level of education, is their students’ knowledge of mathematics. It is rather common to find teachers complaining that their pupils don’t know enough math and, therefore, aren’t able to succeed in physics.

In fact, it has already been sufficiently demonstrated that the absence of some basic mathematical skills is a considerable factor for students' failure in physics courses (Hudson and McIntire, 1977; Hudson and Liberman, 1982). However, it is equally consensual that the domain of these skills doesn't guarantee success in physics; in mathematical terms: they are necessary but not sufficient. Pre-course tests of algebraic and trigonometric skills taken by approximately 200 students initiating a physics course allowed Hudson and McIntire (1977) to conclude that the mathematical pre-test was more a "predictor of failure than a guarantee of success" (pp. 470).

This lack of correlation between the domain of mathematical skills and success in physics courses can be understood if we recognize that using mathematics in physics is something different than simply doing math. This is exactly the position defended by Redish (2005) when he states that:

[...] using math in science (and particularly in physics) is not just doing math. It has a different purpose – representing meaning about physical systems rather than expressing abstract relationships – and it even has a distinct semiotics – the way meaning is put into symbols – from pure mathematics. It almost seems that the “language” of mathematics we use in physics is not the same as the one taught by mathematicians (pp. 1).

Some of these differences are pointed out by the author, such as:

- *We [physicists] have many different kinds of constants – numbers (2, e, π ,...), universal dimensioned constants (e, h, k_B ,...), problem parameters (m, R,...), and initial conditions.*
 - *We blur the distinction between constants and variables.*
 - *We use symbols to stand for ideas rather than quantities.*
 - *We mix “things of physics” and “things of math” when we interpret equations.*
- But perhaps the most dramatic difference is the way we put meaning to our symbols (REDISH, 2005, pp. 2).*

In agreement with Redish (2005), we believe that it is interesting to propose a distinction between technical and structural skills when it comes to analyzing the student's use of mathematics in physics and the comprehension of their interdependence.

The first ones – **technical skills** – are normally developed in math's classes and are related to the technical domain of mathematical systems, such as operations with algorithms, solution of equations, etc. Many physics' teachers associate their students' failure to the lack of domain of these technical skills and it is fairly common to encounter physics teachers complaining that the students cannot “divide with fractional numbers, isolate a variable, solve an equation, calculate the value of a determinant and so on...” It is not uncommon for these teachers to strive in the physical interpretation of problems, even presenting the function that represents the problem's solution, and then say: “from now on it is only mathematics and the solution to this was already presented to you in a previous subject or in math's class”. According to Pietrocola (2008), this implies that once the problem has been understood, from a physical point of view, from then on such competencies are no longer that teacher's responsibility. The transformation of the problem is a mathematical algorithm and solving this would depend on skills learned in other subjects.

As previously mentioned, this posture reflects a naïve/incorrect conception of the deep interrelations between mathematics and physics, once it implies that the former is considered to be a mere tool for the latter (Pietrocola, 2008). When analyzing some standard physics' problems, such as the ones usually found in textbooks, it is not uncommon to realize that the necessary skill to solve it is to find the correct formula, “plug” numbers into it and reach the numerical solution. Those kinds of problems/exercises focus mainly on the “hows”, instead of on the “whys”.

Accordingly, beyond the technical skills, we propose a set of cognitive abilities - namely **structural skills** – which are associated to the capacity of employing the mathematical knowledge for structuring physical situations and recognizing their mutual influence. In this sense, Pietrocola (2002) defends that:

Considering that mathematics is the language that allows the scientist to structure his/her thought in order to comprehend the physical world, science teaching should enable the students to acquire this ability. [...] it is not about just knowing Mathematics and applying this knowledge to physical situations, but being able to apprehend theoretically the “real” through a mathematical structure (PIETROCOLA, 2002, pp.110-111).

Hence, we stand that the acquisition of structural skills should be one of the main goals of physics education. From both epistemological and empirical studies, we have reached a set of five of these skills (competences), which are presented and discussed.

1 - Derive equations from physical principles

Undoubtedly, one of the most important notions of mathematical reasoning is the concept of proof. This notion, which was mainly developed by the Greek mathematicians/philosophers, involves starting from an “evident” set of postulates/axioms and, by logical deductions, being able to prove a certain theorem. This style of reasoning is widely used and exemplified in Euclid’s Elements and can also be found in several Physics’ masterpieces, such as Newton’s Principia and Einstein’s paper on Special Relativity. In spite of the controversial philosophical debate around the “veracity” of the axioms, the idea of proving is more deeply related to the capacity of answering why questions. Presenting and discussing some proofs of the Pythagorean Theorem to the students for example, is definitely very different (better) than simply stating it as a mysterious truth and using it in several exercises/problems.

In physics education, it is also possible to highlight the reasons by demonstrating physical formulae. In this sense, we believe that derivations enhance student’s knowledge about the origin of physics’ equations, allow them to penetrate into the inner structure of physics’ reasoning and avoid the rote memorization of senseless mathematical formulas. Some good examples are the derivation of the law of refraction from Huygens’ or Fermat’s principle or Kepler’s laws from Newton’s dynamic laws. In fact, different ways of deriving the same formula is also recommendable and provide exciting discussions, since it clarifies the flexibility of mathematics. An interesting approach, which also encourages fruitful debates, is confronting these mathematical derivations with the process of obtaining the same law from the analysis of experimental data.

2 - Identify the essential aspects that justify the use of mathematical structures in physical phenomena

Students should be aware of the reasons why a certain mathematical structure is useful for describing a particular physical phenomenon. For instance: trigonometric functions are valuable in physics either because it is necessary to obtain orthogonal components of a vector or because there is some periodicity related to the phenomenon (waves, electric circuits, etc.). Matrices (vectors and tensors) are necessary when the various states of a physical system are represented by groupings of real numbers which cannot be isolated interpreted, each by itself. Returning to the analogy of prefabricated mathematics, it would be as if one were able to find the aisle in the “market of mathematics” where he/she could find what is needed to model a particular phenomenon.

This skill could be accessed by encouraging students to think about the reasons why each physical formula has that particular shape. Some examples can be: What is π doing on the simple pendulum formula? Why is the work done by force a scalar product and the torque a vector product? Why is there a logarithm in Boltzmann law? Naturally, this ability can also be developed in the context of mathematics education if the (physical) motivations for the creation of certain mathematical concepts are mentioned to the students.

3 - Understand the conceptual meaning of physical equations

What does a physical formula mean for the pupils? Tuminaro and Redish (2007) have showed that many students blindly plug quantities into physics’ equations and churn out numeric answers without conceptually understanding the physical implications of their calculations. In their framework, the authors identify this reasoning

as an Epistemic Game called “Plug-and-chug”. One emblematic example found in their results is when a student tries to use $PV = nRT$ to solve a problem and identifies the R as being a radius, which has absolutely no relation to the physical context of the problem.

Therefore, it is imperative that students develop the ability of “reading” physical equations and interpreting their meaning. Bagno and others (2008) have developed an interesting instrument to face up to this challenge. The main idea of this “learning tool” is to demand several tasks related to the interpretation of a physics’ formula, which are: 1) Interpreting the components of the formula; 2) Showing equivalence of units on both sides of the formula; 3) Specifying conditions of application; 4) Describing the relations between the components of the formula by a graph; 5) Analyzing special/boundary cases of the formula; 6) Interpreting assembled components and 7) Giving a verbal representation of the formula.

4 - Recognize the importance of analogical reasoning

Noticeably, one of the most fruitful resources of reasoning in physics is analogy, since the relation between the model and the modeled phenomenon is generally analogical. According to Mary Hesse (1953, pp. 202), “an analogy in physics is a relation, either between two hypotheses, or between a hypothesis and certain experimental results, in which certain aspects of both relata can be *described by the same mathematical formalism*”. This last aspect is particularly important for the development of new theories by formal analogy. In his Analytical Theory of Heat, Fourier (1878, pp. 8) has highlighted the power of analogy by arguing that “mathematical analysis brings together phenomena the most diverse, and *discovers the hidden analogies* which unite them”.

Many physical formulae “look alike”: $y = gt^2/2$, $K = mv^2/2$, $W = kx^2/2$, $E = CV^2/2$. Why are these four equations similar? Some other classical examples of this sort are: Newton’s gravitation law and Coulomb’s law; hydrodynamics and electromagnetism equations; pendulum’s and spring-mass system’s formulae. The explicit discussion of these similarities should highlight the importance of analogical reasoning for physics’ students.

5 - Comprehend the historical mutual influence between mathematics and physics

According to Tzanakis and Thomaidis (2000), any treatment of the history of Mathematics independent of the history of Physics is necessarily incomplete (and vice-versa) and, for that reason, they suggest an historical-genetic teaching approach. This approach recommends that a subject should be taught, only after the learner has been motivated enough to do so by means of questions and problems, which the teaching of the subject may answer. Therefore, such an approach emphasizes less the way of using theories, methods and concepts (technical skills), and more the reasons for which these theories, methods and concepts provide answers to specific problems and questions (structural skills).

For this reason, every historical case-study that clarifies the importance of the relation between mathematics and physics for the essence of scientific knowledge can be a valuable resource in science education. As previously stated, it is highly recommendable to clarify both the importance of physics’ problems as sources of motivation for the creation of mathematical concepts as well as the abstract structures of mathematics acquiring physical signification and interpretation.

Methods

The five structural skills mentioned below are based both on historical/epistemological and empirical studies. However, for the purposes of our research, it is extremely necessary to investigate how these skills can be approached and assessed in real classroom situations. In order to achieve this goal, we have decided to record a set of 13 lessons (around 23 hours) on special relativity given by a professor/physicist from the Physics Institute of the University of São Paulo. We focused our attention in the moments where the professor used mathematical

structures to explain the Theory of Relativity and to solve problems. Due to some students' questions, there were also several episodes where some philosophical discussions about the interrelations between mathematics and physics happened explicitly.

It is important to mention that neither the subject nor the professor were chosen by chance. Since we are interested in analyzing how the structural role of mathematics is approached, special relativity seemed a suitable subject, once it deals with phenomena which are very distant from our daily experiences and are considered counterintuitive. Therefore, it is reasonable to suppose that this topic is more dependent on a rigorous language/formalism provided by mathematical structures.

The particular professor was chosen due to the fact that he's widely admired and recognized, both by his students and colleagues, for having a "different approach" when it comes to discussing several aspects of the nature of Physics, once he normally encourages his students to reason about the physical interpretation of the mathematical formalism. In other words, it can be said that instead of teaching only how to do Physics, this particular professor is very focused on teaching what Physics is really about. In this sense, we were particularly interested in investigating how he deals with the relations between mathematics and physics in his lessons.

Following a similar methodology as the one used by many researchers of problem solving (Larkin *et al*, 1980) who wanted to investigate which cognitive strategies/heuristics were used by experts to solve problems, we believe that we have chosen an expert (both physicist and professor) to analyze how he uses mathematics to structure his thought and how he discusses the role of mathematics in physics (special relativity) with his students.

When analyzing the discourse of a professor inside a classroom, it is imperative to be aware that it is intentional, dependent both on the content and on the audience, and consequently it doesn't exactly reflect the way the professor thinks. Nevertheless, we still believe that the options made by him when preparing and performing his lessons, as well as the philosophical discussions which emerged from the students' questions, can provide some hints about how he interprets the role of mathematics in physical theories and whether or not he uses mathematics to structure his physical thought. In some moments we had doubts concerning some theoretical or methodological options made by the professor, but they were clarified by questioning him during an interview.

From the recordings of the lessons, we have selected three teaching episodes where the discussions about the role of mathematics in physics (special relativity) were present. In the next section, we briefly contextualize the situation that motivated each episode and analyze the discourse of the professor in an attempt to categorize his conceptions.

Results

EPISODE 1: Relativity changed the way Physics was done: "Mathematics could now come first"

In the very first lesson of the course, the professor chose an epistemological discussion by emphasizing that the theory of relativity was a revolution in the way that physics was done. He noted that before relativity, there was a common belief that physical theories should be formulated from the experience (inductivism) and that relativity was responsible for providing a kind of "freedom" from the experimental world, as it allowed physicists to create physical theories based on logical arguments, seeking first mathematical consistency and internal coherence in its principles, and then verifying experimental results. He quoted the case of superstring theory as a current example of a theory that, without any experimental verification, concentrates its efforts in the search for mathematical consistency and is recognized by the physical community, which, according to him, would not be permitted before 1900. The professor reinforces that relativity was responsible for this revolution in the way of looking at physics and even says that Einstein was the one who "liberated". At this point, a student asks a question that demands an explicit answer on the enigmatic relationship between mathematics and physics.

S1: Professor, considering these speculations, what is only a mathematical tool and what is a real physical phenomenon?

P: This is one of the most complicated issues in physics: What is the relation between mathematics and physics? [...] How did Dirac discover the antiparticle? (Writes Dirac's equation on the blackboard: $E^2 = p^2c^2 + m^2c^4$) He thought that the negative sign should have a physical interpretation. How can this set of symbols have any connection with the real world? It has! It's amazing! This is a profound and mysterious relation! It's like your mind has mathematical tentacles that touch the world at distance. Your finger doesn't touch, your mind does. This is weird! But we don't have to think about that when we're working with physics.

From the question raised by the student, it seems that he believes in a distinction between what is "only" a mathematical tool and what is the real physical phenomenon. Several philosophical studies condemn this artificial division between a mathematical and a non-mathematical part of physics¹. In his response, the teacher draws attention to the importance and complexity of the issue and chooses to reflect on a specific case (Dirac's prediction of the antiparticle), rather than speaking generally about the subject.

The example chosen is typical, because it shows that a result obtained within a logical structure, apparently coming from abstract operations, can be interpreted physically, and then detected experimentally. The fascination with the relationship between symbols and the real world becomes clear when the professor confessed that "It's amazing!", and his admiration is similar to Eugene Wigner's classical paper about the unreasonable effectiveness of mathematics in physics:

The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. We should be grateful for it and hope that it will remain valid in future research and that it will extend, for better or for worse, to our pleasure, even though perhaps also to our bafflement, to wide branches of learning (WIGNER, 1967, p. 237).

In arguing that the mind has mathematical tentacles that touch the world at distance, the professor appears to support the hypothesis that mathematics has a structural role in physical thought (Pietrocola, 2008), refuting so the notion of it as a mere tool of physics. However, the final message of this episode is revealing, because it shows that a professional physicist does not need to be aware of this relationship to succeed. The feeling is that in some cases, when the physicist chooses to "consciously disregard" philosophical and metaphysical issues, and sees mathematics as a mere tool, it sometimes enables the progress in his research. This is certainly an important message to an audience of future graduates in physics, but we must question whether it is justified in the context of secondary education.

EPISODE 2: Intuition versus rigorous thought in Relativity – Interpretation of Lorentz Transformations

At the beginning of the third class, the professor warns that relativity is a very difficult topic and it requires a very rigorous thought. In this episode, the discussion on the role of mathematical thinking is more implicit.

P: Folks, what we're studying now is relativity and it is very hard to learn. The main reason is because it violates our intuition. [...] Most of the times you cannot use your intuition because you make mistakes. What is the best way to learn relativity? You have to be rigorous with your thought. For instance, if you make "oral relativity", by saying that time dilates

¹ The physical theory is not something to which mathematics might be added externally, thereby asking ourselves the reason for this effectiveness. The modern and contemporary physical theories are physical-mathematical signs. They are something that **cannot be divided into a mathematical part and non-mathematical part** [...] Therefore, to pose the problem of the effectiveness of mathematics is to pose a false-problem, that is, a problem that does not exist since **mathematics is an indivisible part of the modern and contemporary physics** (BONIOLO and BUDINICH, 2005, p. 86, our emphasis).

In this context, the Lorentz Transformations (LT) are viewed as mathematical operations, which establish a relationship between the coordinates of an event defined in a frame and another moving in constant velocity relatively to the first. If an event has coordinates (x_M, y_M, z_M, t_M) in the frame of Mary - represented in red - the coordinates of the same event in the frame of John (x_J, y_J, z_J, t_J) - blue frame - can be obtained through the L.T.

Certainly, this choice of explaining the conceptual scheme, before deducting and applying the TL, was conscious and greatly facilitated the students' conceptual understanding of the basic elements of the theory of relativity. In this regard, we highlight the importance of interpreting the physical meaning of mathematical formulae (3rd structural skill), as essential to counteract the blind application of mathematical expressions without meaning, so common in physics teaching at various levels. Again, we were convinced that recording and analyzing classes taught by expert professors can be an interesting methodological alternative for this purpose.

EPISODE 3: Covariance of Maxwell's equations: Physical intuition plus Mathematics

At the beginning of the seventh class of relativity, the professor warned his students that that class was "full of counts", but the most important is that they tried to understand the physical meaning of the counts. He also said he would stop addressing problems of the relativistic kinematics and would start working with the problems faced by Einstein when attempting to apply the principle of relativity to electromagnetism.

The scheme presented in the previous episode is mentioned again. The goal now is to write the laws of electromagnetism (Maxwell's equations) in a frame (Maria - red) and apply the Lorentz Transformations to write the components of the electric and magnetic fields measured by another reference (John - blue), which is moving uniformly relative to Maria. The teaching resource of colors is so steeped in the explanatory discourse of the professor, that he says he will try to transform the red equations into blue ones. The condition imposed is that the electromagnetism is covariant, i.e., Maxwell's equations must have the same form in both frames. In a step of the mathematical deduction, one must consider that the terms which represent the components are equal, thus ensuring the desired covariance. At that moment, one student expressed some concerns about the logical validity of this assumption, which motivates a thorough consideration of how physics relates to mathematics.

S2: I'm not convinced that these components should be equal to those. Isn't there a more rigorous way of proving that?

P: This is a central question for understanding what physics really is. Can you demonstrate this equality from a mathematical point of view? The answer is no! But physics only cares about mathematics when it's important, and now it's not. Physics is not logic, it tries to make an image of nature. The guy who did this was hoping that it would be possible. He wants to believe in the first principle of relativity. Why? Because it is beautiful!

Probably the student's question was motivated by a habit of demonstrating logically every physical statement. In this manifestation, the professor sees a great opportunity to break with this belief and to emphasize that physics is very dependent on mathematics, but not limited to it. According Pincock (2007), mathematics is "metaphysically dispensable, as mathematical entities, if they existed, would lack a relevant causal role in the physical world" (PINCOCK, 2007, pp. 253). The discourse of the professor in this episode indicates an agreement with this philosophical stance, at least for this particular case.

It is also important notice that this fundamental debate was only possible because the professor decided to derive the expressions (1st structural skill) that relate the components of the electric and magnetic fields in both frames of reference, instead of just presenting them as "magical" formulae.

P: Physics is made by a bunch of intuition plus a bunch of logic. [...] Mathematics carries me... [...] When you put together physical intuition and mathematics it is much more than just mathematics. You make math your slave, not your boss. I'm the boss, physics! Why? Because I want to understand the world and it's not made of mathematics. If you live inside

this world (draws a rectangle), logic cannot allow you to get out of it. If you want to leave this world, you have jump. That's exactly what Einstein did.

At first, the professor emphasizes the harmonious marriage between mathematics and physics, highlighting that the latter is made by intuition plus logic. However, this particular example seems to reveal a conception that there is a hierarchy in this relationship and, apparently overcome with emotion, the professor argues that physics is the boss and that it only cares about the math when it matters. Moreover, philosophical beliefs are mentioned when he claimed that the “world is not made of mathematics”. It is interesting to observe that these views are very personal and it is perfectly possible to find different positions among physicists and philosophers.

The message that we live in a world (rectangle) and only with the logic we can not get out of it is exemplary. In fact, some philosophers of mathematics, Poincaré among them, would agree with this notion by arguing that mathematics itself is not confined to logic, once intuition plays a central role in the creation of mathematical entities. The final message of the episode is that the logic itself doesn't allow us to extrapolate the world we live in, if one wants to do that one needs to jump. These jumps do not occur frequently in the history of science and are typically achieved after years of effort and logical-deductive reasoning. According to this conception, mathematics guides the reasoning of the physicist, shows the errors he committed, but is not enough to provide the necessary jumps to create his theories. In that exact sense, the principle of relativity is not logically provable.

Conclusions and Implications

This work is part of a doctoral research that has been developed to investigate the interrelations between mathematics and physics in order to identify possible implications for teaching. Considering the complexity of the topic, there are several possible approaches to treat it (historical, epistemological, cognitive, etc.). Our main goal is to focus on the structural role of mathematics by differentiating technical from structural skills and analyzing the possibilities of developing the latter ones. The methodological approach adopted here was to investigate how this structural role is discussed in the context of physics teaching, by analyzing the lessons of a professor (and physicist), widely recognized as an expert on the subject.

The analysis of the episodes allowed us to identify a range of possibilities to categorize the use of mathematics in physics and the understanding of their interdependence. The idea that mathematics has a structural role in physical thought was present in the professor discourse at various times, especially when he recommended the abandonment of intuition and warned of the inability of natural language to deal with problems faced by special relativity. However, the search for a generalization of the role of mathematics seems to be unfeasible. What is more prudent is the analysis of this discussion in various contexts, varying both the professors and the physical content taught in their classes.

It is possible to locate several moments where the professor is particularly concerned with the development of structural skills, especially when he chose to mathematically derive relativity formulae (1st structural skill) and when he focused on the conceptual understanding of the Lorentz Transformations (3rd structural skill). Nevertheless, it seems that he is also very interested in conducting philosophical debates with his students and questioning the “mysterious” relation between mathematics and physics, which seemed a rather unusual posture for a theoretical physicist. For the sequence of this work, we intend to strengthen our set of structural skills both by epistemological arguments and by analyzing their development in real classroom situations.

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GENERATING SCIENTIFIC KNOWLEDGE IN OPTICS VIA PHENOMENOLOGY

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Abstract

By doing phenomenology in science education students evolve their scientific thinking primarily via a phenomenon-based – i.e. in dialogue with nature – rather than the popular theory-based method. Phenomenological knowledge generation attempts to bridge the gap between immediate perceptions and theoretical conceptions. Considering the basic tools of a phenomenological approach to optics and sketching their application to even advanced optics we investigate the emergence of those conceptions. We show how students learn to analyse an experimental setting by looking into a mirror or investigating a lighting fixture through a lens or a grating. Beginning with a number of observations they immerse themselves in the setting and transform the observations into a scientific view. The framework of the investigations thus starts with the living subject and his/her different modes of experience rather than with the separation of subject and object used by Descartes. There are essentially two modes of experience that can be distinguished by doing phenomenology, the centric (perceptual) and eccentric (conceptual) position.

Introduction and the framework of phenomenology

A research review of doing phenomenology in science education was recently published by Ostergaard, Dahlin and Hugo (2008). They concerned themselves with phenomenology in science education as a means of helping students to bridge the gap between the “life world” and the “science world”. By distinguishing three categories – phenomenology *of* science education, phenomenology *in* science education and phenomenology and science education *integrated* – they refer to different approaches, each of them having the same aim, to make science less foreign or alienating to students and to render more transparent the way in which scientific conceptions or the structure of scientific content are connected with everyday experiences of the life world.

The idea of phenomenology *in* science education entails phenomenology as a pedagogical approach to various phenomena in nature. As a possible first step students learn to observe and carefully describe phenomena usually presented and concentrated in a series of experiments. The series are used to show how a phenomenon can change under different experimental conditions. As a second step the observations are rationally ordered. By constructing a rational order scientific knowledge is condensed or concentrated. But the way of scientific knowledge generation is not merely a decision-making and mandatory narrow path to a single insight which is then considered as the explanation, but rather involves conducting one’s thinking based on the prerequisites of the chosen method. In the epistemological framework of phenomenology the students’ thinking is challenged to evolve in dialogue with a natural order found in a series of experiments. Producing ideas and the anticipation of order should interact as closely as possible with the experimental results. Here, the aim of science knowledge building is not necessarily an

abstract separation from perception, but an endeavour to keep an inseparable connection with immediate perceptions (Boehme, 1987). The so-called network generated between observations and conceptions (Hoettecke, 2007) becomes more closely meshed while its shape is determined by the phenomenological approach.

Starting with simple examples we will discuss how scientific knowledge can be constructed in such a phenomenological approach to optics. Its epistemological framework will be derived and finally consequences for doing phenomenology in a learning situation will be presented.

Doing phenomenology in optics – examples

Realising visual depth, a first tool of phenomenological optics

The visual depth of a perceived object can be realised through different perceptions: the accommodation of our eyes' lenses, the binocular alignment of our two eyes, the extension of objects in our visual field (perspective) and the shift of objects in correspondence to changing our point of view (parallax) (Mackensen, 1994). Especially the larger and smaller lengths of our fingers in our visual field can be correlated to a smaller or larger distance from our eyes, since we are convinced in accordance to our body experience that the size of our fingers does not change by varying the distance between our eyes and our fingers. So the *perception of several senses* enables us to size up visual depth with respect to the perspective. Those perceptions are connected in the (geometrical) conception of distance.

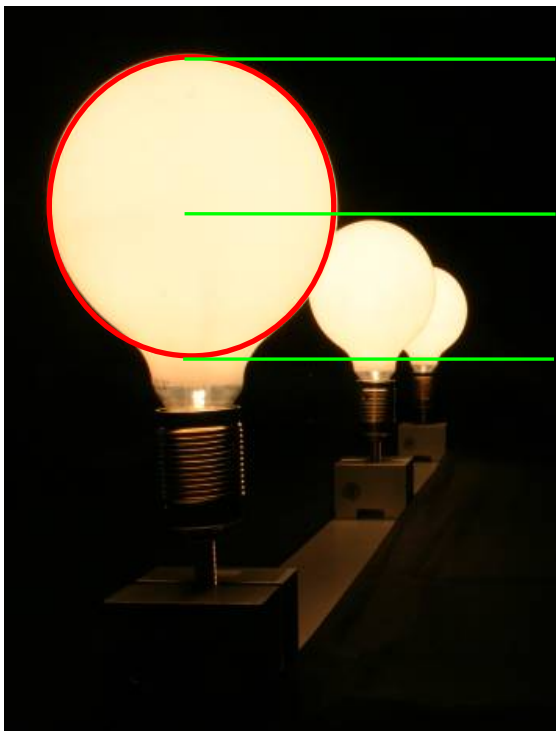


Figure 1. Three identical lamps equally spaced in a line with the unit equal to the distance of the observers' eye and the first lamp. The observed radius of the second lamp is half that of the first lamp, its dimension in the visual field, a quarter of the first lamp. All lamps are seen equally bright.

For example this concept is integrated into the "life world" by seeing a tree-lined road. An experimental setting of three identical lamps equally spaced in a straight line enables students to observe the details (Figure 1). By sketching the experimental setup they can correlate their observations with the geometrical ideas using the intercept theorems (Figure 2).

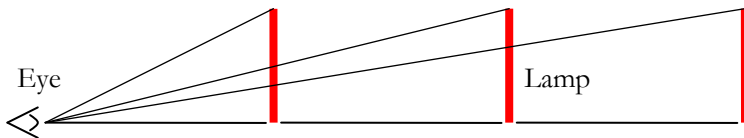


Figure 2. Schematic diagram of the experimental setup of Figure 1.

From the obstruction of different edges to lines of sight, a second tool

It is an everyday experience that if my one thumb is in the line of sight of the other, the front thumb will obstruct the rear thumb. By growing up we have learned to develop a conceptual mode in which we correlate the smoothness of plane objects and the obstruction of parallel edges: the concept of straight lines. Once again we connect the perceptions of several senses and develop a conception. Our experiences as an embodied self enable us to construct this concept. It can be regarded as a geometrical element which condenses a set of (possible) experiences. The geometrical elements can be drawn in the setting of an optical experiment in order to summarize and visualise possible observations. They are typical in a scientific context. Here they are not regarded as physical objects (rays of light) but are rather used as geometrical operators derived from perceptions. The scientific learning situation tries to maintain this connection.

Parallax, a third tool

We usually realize the obstruction of parallel edges by closing one eye and moving our head. In our visual field *nearer edges or objects are then shifted much quicker than more distant ones*. Parallax is another tool that contributes to our conception of distance (Figure 3). In his ecological approach to visual perception Gibson (1979) discusses how natural vision is constructed by an embodied self that walks up to something interesting and moves around it so as to see it from all sides. The very strong correlation of movement with viewing has also been examined by other authors (Jonas, 1973). By introducing parallax as a further tool to students we are again picking up this discussion while taking into account the fact that natural vision depends on the eyes *in the head on a body supported by the ground*. (According to Gibson and Fuchs (2008) in this context the brain is regarded as the central organ of a *complete* visual system).

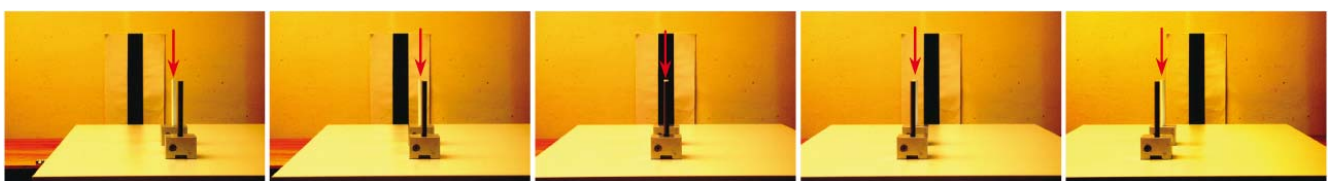


Figure 3. Parallax and the conception of distance. In the visual field of an observer who moves from the left to the right the table is shifted to the left: the nearer the bar, the stronger the shift.

Perhaps the most famous application of these tools: Looking in a mirror

The application of the tools to the images we see in a mirror leads to the astonishing fact that the mirror ceases to be an active interface (classical optics) and behaves rather like a window. This liberates the mind to look into a novel optical space (Maier, 1993). Each feature for realising visual depth is not only valid in the space in front of the mirror but also in the space beyond the mirror. – A recently published paper presents the idea that the notion of optical space of the mirror need not be confined to an elementary level course but can also be done at advanced level to describe an optical feedback suppressor and the diffraction pattern of 3D-grating created by two mirror

images of a plane cross-shaped grating. These topics can be developed on the basis of the abovementioned tools as well (Grebe-Ellis, 2008).

Applying these tools to images seen through a lens

A small lamp that does not burn too brightly is located one focal length from a lens. In accordance with the first tool the visual depth of the lamp is investigated by perspective and parallax. The observed results are:

1. The dimensions of the lamp in the visual field of the observer do not change as the observers distance from the lens varies. The perspective is preserved (Figure 4). These observations show that *each* point of the lamp is correlated with *one direction* of view. Figure 5 conceptualizes this by introducing rays. For example, in position 4 one end of the lamp is seen by aiming through the upper part of the lens. Ray number 4 shows how the direction of view is preserved.

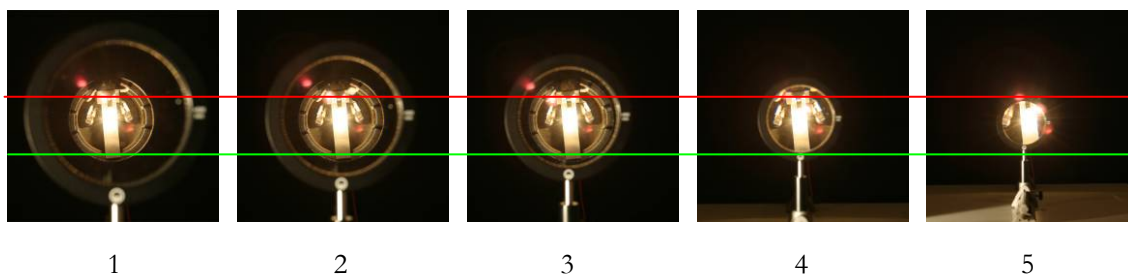


Figure 4. Images of a lamp located one focal length from a lens. The dimensions of the lamp in the visual field do not change by enlarging the distance to the lens from position 1 to 5 (freezing perspective). The dimensions of the lens-mounting become smaller (regular perspective).

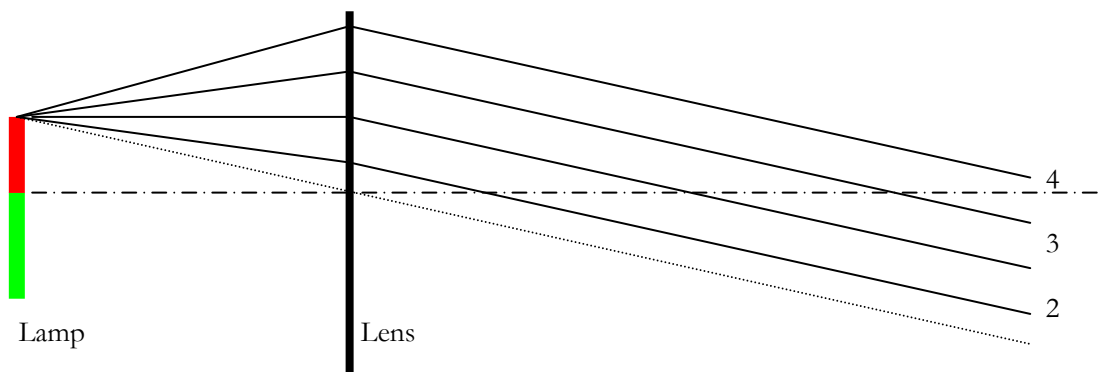


Figure 5. Lateral view. Rays are introduced to conceptualize the observations of the experimental setup of Figure 4.

2. When the observer moves from side to side the bar shifts too. These shifts correspond to the image of the bar, being infinitely far away (Figure 6). Using the second and third tool mentioned above to visualise this result it is necessary to introduce parallel lines of sight, since to an infinite distance the same direction always corresponds (Figure 7). In this way it is possible to correlate the geometrical concept of rays to a set of observations. We already explained that in our opinion those observations may bridge the gap between the perceptions of viewing and a

scientific visualisation. Furthermore those rays, introduced as geometrical operators, can – but must not – be used to show the interrelation to the ray model of light. Phenomenology thus sets a framework in which the special features of a model can be discussed and the construction of physical objects through developing a model become apparent.



Figure 6. The part of the bar seen through the lens is seen infinitely far away (no left shift during the observers move from the left to the right).

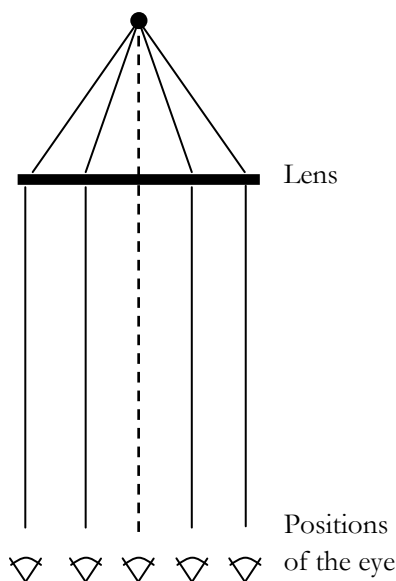


Figure 7. Rays are introduced to conceptualize the observations of the experimental setup of Figure 6 using the second (obstruction) and the third tool (parallax).

Applying these tools to images seen through a lens and a grating

By modifying the experimental setup and introducing a grating additionally, not only one lamp, but a set of (differently coloured) lamps is seen. Now the tools can be used to describe diffraction (Sommer, 2005). As shown elsewhere the results obtained can be formulated using Wagenschein's suggestions for doing phenomenology (Figure 8). If a grating is illuminated from a single direction perpendicular to the grating plane a set of illuminating directions is observed. This set can be described using right-angled triangles. The legs of those right-angled triangles opposite to the inclination angle are integral multiples of a basic length λ^* . If the grating constant is chosen as hypotenuse of those triangles the basic length is equal to the wavelength λ (Grebe-Ellis, 2006). – By taking this path of knowledge generation, the conception provides both the connection to observations and to the wave model of light. It serves as a framework of reference for the discussion of several ways of scientific knowledge generation.

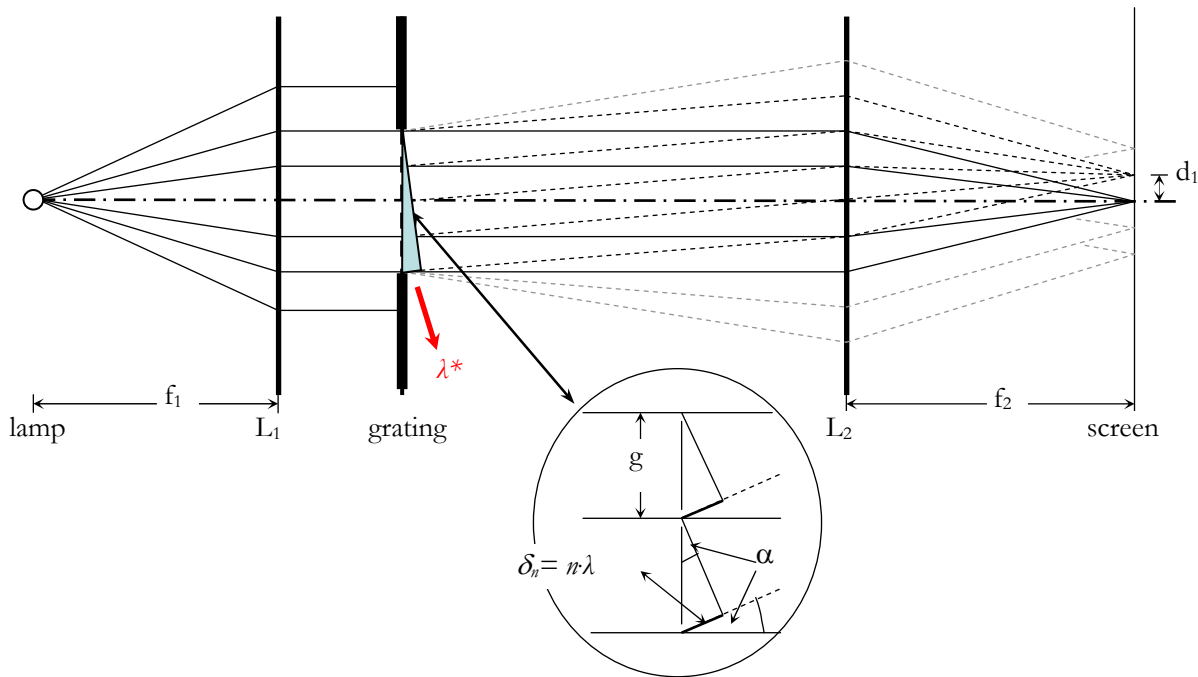


Figure 8. Experimental setup for diffraction. The grating is illuminated in a single direction from the lens L_1 . Behind the grating there is a set of directions spatially separated by the lens L_2 .

Conclusion

What does this way of doing phenomenology in optics imply? – The centric position of students by having immediate perceptions and the eccentric position by developing conceptions with respect to their experiences in the centric position constitute a unity. This unity provides the embodied self as a living subject (Fuchs, 2000). One living mode can be characterised as immediate connection (centric), the other, as the creation of distance (developing conceptions, eccentric). Thus scientific knowledge acquisition by doing phenomenology means a learning situation in which the students can live in both modes and experience the connection between them during their learning. The epistemological framework starts with the living subject and not, as does Descartes, with the separation of subject and object.

On the one hand doing phenomenology within this framework can be a point of departure to various teaching activities such as hands-on experiments of the students, demonstration experiments, more or less guided instructional approaches and so forth. On the other hand it can be used to balance out the teaching of the content of science and of the nature of science. Phenomenology is not only closely linked to various phenomena in nature but also to discussions about methodological issues as well as the epistemological status of scientific knowledge.

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ARGUMENTATION ABOUT AND UNDERSTANDING OF SCIENCE: RESEARCH EXPLORING HOW TO INTERRELATE THESE TWO DIFFERENT PERSPECTIVES

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Abstract

Since the mid 90th research has increasingly focused on students' argumentation. Science educators not only argue that argumentation is an important aspect of science education in general; it is also assumed that argumentation promotes the learning of the science content. Conversely, research indicates that students' ability to argue is limited by their content specific knowledge. Even though these two claims are made, research rarely explicitly addresses the interrelationship between argumentation (learning about science) and conceptual understanding (learning of science). Research reported in this symposium explicitly addresses students' argumentation and how students incorporate conceptual understanding while they argue. The three projects focus explicitly or implicitly on distinguishing different qualities in students' argumentation and their conceptual understanding of the content which they deploy into their argumentation.

Introduction to the Symposium

Since the mid 90th research has increasingly focused on students' argumentation (e.g., Erduran & Jiménez-Aleixandre, 2008). Science educators not only argue that argumentation is an important aspect of science education in general; it is also assumed that argumentation promotes the learning of the science content (e.g., Zohar & Nemet, 2002). Conversely, research indicates that students' ability to argue is limited by their content specific knowledge (e.g., Means & Voss, 1996; Sadler, 2004). Even though these two claims are made, research rarely explicitly addresses the interrelationship between argumentation (learning *about* science) and conceptual understanding (learning *of* science).

Partly, this problem might be caused by different approaches towards learning in these two areas. Whereas research on argumentation often addresses the *processes* of students' activities (that is, their discourse about a topic or a task), research on students' conceptual learning typically focuses on the *outcomes* of such processes (that is, students' conceptions at a specific point in time). Only rarely does research on students' conceptions focus on how students utilize their conceptual understanding while acting in "normal" learning settings. As a consequence, research aiming to interrelate argumentation and conceptual understanding typically addresses students' conception prior and/or post to instruction which focuses on argumentation but not *during* this instruction (e.g., Zohar & Nemet, 2002). Another methodological limitation in current projects is the idea of "quality" as a means to distinguish "good" from "poor" argumentation. Studies in science education typically offer at least two different approaches with either a content-oriented or a more structure-oriented focus (or a mixture of both). On the one hand, students' argumentation being of high quality is assumed, when students' argumentation shows high relevance between data and claim (e.g. Means & Voss, 1996). On the other hand, the quality of an argumentation is assumed to increase when it consists of more justifications, which also rebut alternative arguments (e.g., Jiménez et al., 2005; Osborne et al., 2004; Zohar & Nemet, 2002). However, the quality of an argumentation might also differ in terms of the quality of conceptual understanding incorporated (e.g., v. Aufschnaiter et al., 2008). This is not solely a problem of "correct" or "incorrect" knowledge but also an issue of "advanced" or less "advanced" understanding, leading to improved argumentation.

Research reported in this symposium explicitly addresses students' argumentation and how students incorporate conceptual understanding *while* they argue. All three projects focus explicitly or implicitly on distinguishing different qualities in students' argumentation and their conceptual understanding of the content which they deploy into their argumentation. Furthermore, the projects comprise science issues (biology, chemistry, and physics) as well as socioscientific issues. These different approaches, all with a common focus, aim to shed (more) light into the debate on how argumentation and conceptual understanding interrelate. Such an understanding would improve both, the teaching *about* science and the teaching *of* science.

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ARGUMENTATION & SCIENTIFIC CONCEPTIONS IN PEER DISCUSSIONS: A COMPARISON BETWEEN CATALAN & ENGLISH STUDENTS

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Abstract

The purpose of this study is to compare the arguments used by English and Catalan Pre-service Primary Teachers students in peer discussions about two scientific tasks. The comparison is based on argumentative schemes of their arguments as well as on ideas, conceptions and beliefs that are in their base. The analysis is carried out at three levels. At the first level, we compare the number of arguments by tasks and by country; at the second level, we analyse arguments and make a comparison between types of argumentative schemes by tasks and by countries. More in depth, qualitative descriptions were carried out in order to illustrate the similarities and differences between the Catalan and English students' arguments and scientific conceptions. Results illustrate that the arguments generated by students are quite similar in both samples in terms of number of arguments and frequencies of types of arguments, but with some differences in the order of these frequencies related to specific tasks. More relevant is the qualitative difference in the way that appellations are made to give evidence and theories, given the identification of premises and argumentative schemes; this favours good understanding of scientific knowledge.

Introduction

With respect to the aim of our research, there have been attempts to identify general patterns of reasoning that were not related to a specific content of the questionnaire or the interview, commonly used in research about science conceptions of students and that in some way could explain the ideas of students (Andersson, 1986; Guidoni, 1985, 1990; Maurines, 1991; Rozier and Viennot, 1991; Viennot, 1996). Researchers from different fields have given other interpretations of these conceptions, in some cases, through cognitive entities as “schemes”, “p-prims”, “mental models”, and so on (Rumelhart, 1980; DiSessa, 1980; Genter and Stevens, 1983; Gutiérrez & Ogborn, 1992). These works contribute to our thinking that beneath the specific forms of reasoning of the students some common or general ways of reasoning, or patterns of argumentation schemes, can be found. As our hypothesis is that these ways of reasoning or types of arguments are learnt by students in society and mainly outside the school, there may be differences among different communities. Our research proposes to find these differences between Catalan and English students, so that this research will contribute to comparative studies (related to argumentation) that are scarce in the literature.

As our interest is mainly on types of patterns of arguments to compare the reasoning of Catalan and English students related to scientific activities, we suppose that theories of argumentation that consider argumentative schemes could provide an interesting framework for our research, which will give a new way to better understand the scientific conceptions of the students and will ease that comparison.

Theoretical framework

As we are interested on the spontaneous argumentation of the students that are plausible and related to solve a difference of opinion, both frameworks that consider the argumentation as a social practice to convince and critical dialogues will be useful. As we try to compare arguments, theories that focus mainly on types of arguments are suitable. Thus, we use the Theory of Argumentation from Perelman & Olbrecht-Tyteca (1958) and the Schemes for Presumptive Reasoning of Walton (1996, 2006), which will be complemented with some of Aristotle's "topoi" because they provide us with common sense argumentative schemes and premises, which we expect to find in the discussions of the students. These theoretical bases have been used in science education research only in few studies (Duschl and Guitomer, 1997; Pontecorvo & Giradei, 1993; Jimenez-Aleixandre et al., 2000; Sandoval and Millwood, 2005; Duschl, 2007; Fagúndez & Castells, 2007; Konstantinidou, 2008); our research will extend those works trying to combine several theories of argumentation in our analytical framework and thus, we will contribute to the theoretical level in relation to argumentation as well. We presented these theories of argumentation in previous papers (Castells et al., 2007; Konstantinidou & Castells, 2008), we will not comment about them here because of space.

According to our perspectives, we consider an argument consisting of a thesis, one or several premises and the scheme that allows the transference of the accepted premises to the thesis or conclusion. We have to see these elements, not in a lineal direction, but interrelated among them. We share the Perelman's (1982) notion of premise, that means, the data or agreements on which the arguments are built. The premises can be of several types. From the real: facts¹, truths or theories and presumptions. From the preferable: values, hierarchies of values and "loci"². The argumentative schemes of single arguments are the discursive structures that allow to transfer the agreements from the premises to the theses. These argumentative schemes are categorized differently according the theory of argumentation considered, but many of those categories, coming from different theories, may share characteristics that makes sense we combine those categories in some new ones.

Methods and Samples

The *aim* of the research is to compare arguments of Catalan and English Pre-service Primary Trainee Teachers in small discussion groups about scientific tasks and to infer and explain about the scientific misconceptions of the students. This is part of a wider research about qualitative comparison of the spontaneous argumentation³ of the students.

Our interest focuses on types of patterns of arguments, or argumentative schemes, to explain the scientific conceptions of the students and, given that we use categories from several Theories of Argumentation, we will also contribute to the theoretical level in relation to argumentation.

Research questions

¹ Facts are universal agreements, and therefore unquestionable. An argument gains convincing force if it is based on facts (Perelman & Olbrechts-Tyteca, 1958)

² General *Loci*: They are premises of general carácter that are useful for all sciences and all kind of discursive genres. They are affirmations about what is presumed to be of higher value in any circumstances whatsoever, (Perelman & Olbrechts-Tyteca, 1958; Perelman, 1982)

³ The wider research comparing English and Catalan students argumentation about scientific and socioscientific tasks have received the support of the Anglo-Catalan Society and the DURSI (Generalitat de Catalunya) by the Project with Reference N. 2006 PBR 10019 based at University of Barcelona in collaboration with University of Bristol.

What types of argumentative schemes can we find in the argumentations of the students? Are they related to countries? Are they related to specific tasks?

What type of premises (facts, theories or values) are the arguments of the students based on? Are these premises related to the tasks? And to the countries?

Which scientific conceptions of the students can be drawn from their premises and thesis? Are they related to the countries?

Data collection and analysis

The **data** comes from the transcriptions of the discussions of students among their peers about two tasks: (1) free falling and (2) floating and sinking and climate change.

Task 1: *Free fall and the spit*. A physics problem was presented in the form of a cartoon taken from a magazine which has no connection with physics teaching or scientific popularization materials. The situation is about a man that first throws a spit from a window in a building of several flats and then, he throws himself down from the same window. (See Annex in Konstantinidou et al. In this Symposium)

Task 2: *Floating and sinking and climate change*. A physics and social problem is presented in the form of a picture with ice floating on the water, where the students have to do a prediction and, afterwards another picture of what will happen in reality is shown to students. Then, they have to argue about this result compared to their predictions and after, students have to relate the specific case of these pictures to the climate change in the world. (See Annex at the end of this paper)

Three groups of students in Bristol and three groups of students in Barcelona participate in the research. The groups were between three and five volunteer students. All the groups performed the tasks outside the timetable of classes in the university. Students didn't receive specific instructions about the scientific topics of the tasks, neither about argumentation. A researcher was in the room during the discussions, but her role was only to give general instructions and enforce the conversation with neutral questions if she realised that it was appropriate.

The **analysis** is carried out at several levels. At the first level, we identified arguments by means of thesis, in each argument we identify thesis, premises and argumentative schemes or patterns of the argument and we compare the number of arguments by tasks and by country; at the second level, we make a comparison between types of argumentative schemes by tasks and by countries. Frequency counts were recorded giving a quantitative indication of arguments generated and of types of argumentative schemes. More in depth, qualitative descriptions are also carried out in order to illustrate the similarities and differences between the arguments of the teachers of Catalan and English students and their scientific conceptions. Based on the results, we try to explain certain ideas or scientific conceptions more frequently found in one or other country, or task. We will present here the analysis done in a specific argument to illustrate how we proceed.

However, the analysis is not easy because in the interventions of the students there are many incomplete arguments or many implicit parts of the arguments we have to suppose; very often we would need information about the ideas of the students or the patterns of reasoning to “understand” what they “want” to say. Also the real argumentation in which we isolate arguments make them to lose their meanings. There are different possible levels of argumentation to consider. For example, the previous case could be analyzed taking in consideration partial arguments that integrate the global argument, the arguments form a series of arguments that goes in the same direction to the thesis that affirm there is climate change. Our level for the analysis of arguments is intermediate focusing in the main ideas students use to argue.

Table 1: Analysis of an Argument from the Ice task

<i>Student intervention:</i> "...And more, the climate change makes that the heat arrive before and makes that the trees produce flowers before and that in February the allergies begin because of the pollen although they would have to begin at the end of March..."
<i>Thesis:</i> There is climate change (implicit)
<i>Premises:</i> 1) The climate change makes the heat arrive before (truth or presumption) 2) The flowers of the trees bloom before (fact) 3) The flowers produce pollen (fact or truth) 4) The allergies begin in February before the normal time at the end of March) (fact) 5) The allergies are caused by the pollen (truth)
<i>Description of the Argument:</i> We know that the climate change is produced because there are events that are consequence of the climate change.
<i>Argumentative scheme:</i> Facts and consequences
<i>About the scheme:</i> In using this scheme the speaker asserts that because certain events exist, then certain other events can be expected to exist either simultaneously or subsequent in time as a result of the first events. (Walton, 1996, 2006) It is a scheme based on a causal nexus, a type of linkage of coexistence that is supported by a structure of reality, (Perelman & Olbrecht-Tyteca, 1958)

Analysis and Results

Counting Arguments and Types of Argumentative Schemes

a) There is no difference between countries related the total number of arguments identified in the two tasks together, neither related to the number of arguments per minute. This number is bigger in Barcelona but the difference is not considerable. We measure the number of arguments per minute defined by the relation between the total number of arguments in the whole activity and the mean of the duration time of each activity.

b) The Ice task facilitates giving more arguments than the spit task although the number of arguments per minute is bigger in the spit task. We think that this result is influenced by the way we presented the tasks; in the ice task, students had to do a prediction first, then we gave them the result in a picture and they had to argue about it, and finally, they had to think about the climate, whereas in the Spit task there is only a demand.

c) The general tendency in the total number of arguments by task and in the number of arguments per minute is very similar between countries. In both countries, the ice task tends to give more arguments but the rate of the argumentation is bigger in the spit task. We can interpret these results because the spit task treats a situation that is more familiar to students than the one of the ice task in both countries. Students have possible arguments on hand more easily. Evermore, in the ice task there are two different contexts, and so this task is more complex for the students.

Specifying the analytical framework

Our analytical framework combines the list of schemes of Perelman (1962) and the list of schemes of Walton (1996, 2006), which are completed by some topics of Aristotle (IV bC). We have proceeded from the theoretical framework to the analysis and *vice versa* several times. That means, from the lists of schemes (Perelman, Walton) we identified some schemes in the arguments of students in the recorded discussions. We compare schemes that are similar to Perelman's and to Walton's list of scheme. From the identified schemes in the dialogues, we elaborate a list of type of argumentative schemes, which joint the categories of these authors and in some cases

combine with arguments (topics) of Aristotle in new big categories. We presented a first version of this analytical framework at the GIREP 2008 Conference (Castells, Erduran & Konstantinidou, 2008), which we change in some points here from our last analysis. At following we give the list of these main categories of the synthesis we have used in this paper, the list is still provisional, more analysis is need and it could produce new changes in this list of Types of Schemes:

Table 4. Summary counting arguments by tasks and separated countries (Bristol / Bcn)

Task Bristol	Total Number of Arg.	Number of Argument per minute
Spit	40	2.17
Ice melting	59	1.60
Total	99	1.79

Task Bcn	Total Number of Arg.	Number Argument per minute
Spit	43	2.09
Ice melting	56	1.64
Total	99	1.81

Quasilogical arg. based on Logical Relations (transitivity, implications from a rule; implications from a classification, implications from a definition, contradiction and incompatibility, from the proper -several topics from Aristotle-, etc.)

Quasilogical arg. based on Mathematical Relations (by identity/rule of justice, of reciprocity or symmetry, by the inverse, of compensation, of complementarity, of contradiction, of comparison (by the sacrifice), of all and parts, of division/addition, by probabilities, etc.)

Facts and Consequences (pragmatic argument, argument by mean and end; from correlation to hypothesis, from correlation to cause, from cause to effect, from effect to cause, from consequences, from sign, etc.) (Linkages of Succession)

Gradualism (the procedure by stages, of direction, the soaped slope or of the finger in the gear, from gradualism, of the slippery slope, of propagation, of overcoming, of unlimited development, etc.)

The Waste (of waste, of sacrifice, based on opportunity, of shortcoming, of redundancy, of the decisive, etc.)

Group and Component (liaison of coexistence: person & acts; group & individual, essence & correlation, body and physical behaviour, by commitment, arg. against person, etc.)

From Social Acceptation (by authority or expert opinion-person, text, institution, scholar rule, from popularity, ethotic argument, topics of quantity and topics of quality, etc.)

Double Hierarchy (DH, of degree and order, by more -> more, arg. A *Fortiori*)

By the Particular case (by the example, by the illustration, by the precedence, by the model)

Analogy (analogy, metaphor)

Some examples of arguments to illustrate argumentative schemes

We will illustrate some of these categories with other cases from Bristol or from Barcelona, in the next cases we also will comment about the identified premises.

In what student S1 says we interpret in “it adds to the volume of the water”, this “it” as a volume, the volume 2, marked in the first drawing of the figure 1. The student’s argument, as a whole, seems related to a specific “geometrical view” of the situation, he “sees” the line of the water’s level separating the content of the beaker (volume 1) from the part of the ice above of the level 1 line (volume 2). So, for this student, when the ice melts, its water volume is added to the volume 1 of the beaker and so, the level will rise. We present in the following table the analysis done. From his intervention, we can think student S1 perhaps would share a misconception: “The volume of the water don’t change when it change to ice and vice-versa”.

Table 5. Analysis of arguments in a student S1 intervention about the Ice task

<i>Student S1 intervention:</i> “I think the water will rise when the ice melts. As the ice melts it adds to the volume of the water, therefore increasing the water level”
<i>Thesis:</i> The water will rise when the ice melts.
<i>Premises:</i> 1) As the ice melts, it adds to the volume of the water, (fact) 2) If the volume of the water in a beaker increases, the level of the water will rise. (implicit fact)
<i>Description of the Argument:</i> Quasilogical of Mathematics Relationship (a type of argument by Division, related to the mathematics relationship of Addition)
<i>About the scheme:</i> It is a type of Quasilogical argument into the type of arguments by Division which, from the identified parts, assumes the sum of parts equals the whole and thus infers about the whole from the parts or <i>viceversa</i> .

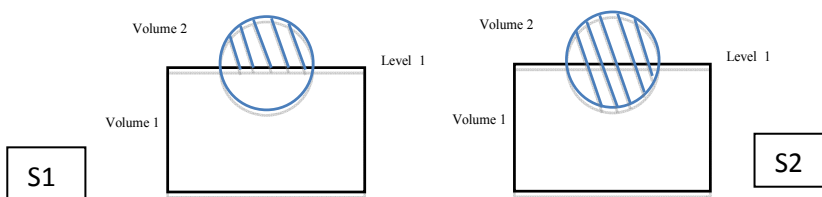


Figure 1. Representation of the geometrical views of the initial situation of the Ice task of S1 and S2

Table 6. Analysis of arguments in a student S2 intervention about the Ice task.

<i>Student S2 intervention:</i> “I think that the water level will stay the same, because when the ice is <u>first</u> added to the water, displacement takes place forcing the water level to rise. <u>As the ice melts</u> this would counteract the displacement, but obviously the melted water <u>would add</u> to the volume, therefore creating a <u>neutral effect</u> where the water level would stay the same”.
<i>Thesis:</i> The level of the water will stay the same
<i>Description of the argument:</i> It is a complex argument that includes several arguments. As a whole, we can identify a Method or Device of Stages (Perelman, 1982) but in every stage we can identified other alone arguments. The sequence in the argumentation of student S2 is the following: 1 st) There is a specific level of water when no ice is in the beaker (level 1), 2 nd) the solid ice system is put into the water and so, the level of the water will rise (level 2), 3 rd) when the ice melts (the solid disappears) the level of the water would have to decrease, but 4 th) as the water from the melted ice is added to the water of the beaker, it will compensate the decreasing, and the level of the water will be the same.
<i>Scheme:</i> In the 2 nd stage and the 3 rd stage we can identify Quasilogical schemes of Logical Implication; and in the 4 th stage, the scheme is a Quasilogical of Compensation (based on mathematical relations). Together is a Method or Device of Stages.
<i>About the Scheme:</i> The Method or Device of Stages is a method used when the gap between the theses the audience accepts and those the speaker defends is too great to be overcome all at once, it is advisable to divide the difficulty and arrive at the same result gradually. Quasilogical Scheme of Logical Implication are schemes which claim to be rational because they resemble the patterns of formal reasoning as Implications from a Law or Theory, Implications from a Classification or from a Definition, etc. Quasilogical of Compensation is a type of scheme based on a mathematics relation of

In this case, we can interpret that student S2 has a “geometrical view” of the situation as the volume 2 of ice differentiated from the volume 1 of the water of the beaker; in this view, the ice is considered an external system from the water of the beaker.

With the previous examples, we try to show that the study of argumentation in real contexts is more than identifying thesis, premises and schemes. In this last example, student S2 seems to use a sequential reasoning, a type of general reasoning identified by other researchers (Viennot, 1996; Castells, 2001). For this case, we may conclude that the student S2 gives an incorrect answer because he has argued by Device of Stages in a not appropriated way to this situation, which impedes him to have a global appreciation of the situation.

Percentages of types of argumentative schemes in the total sample

There are types of argumentative schemes that are found with bigger frequency than others in our sample. The order of the percentages of the types of argumentative schemes identified counted in the total sample (Bristol and Barcelona) (198 arguments) can be read in the figure 2, the type of schemes that have the biggest percentages are into de group of Quasilogical Based on Mathematics Relations schemes. It is not a strange result considering we proposed scientific tasks.

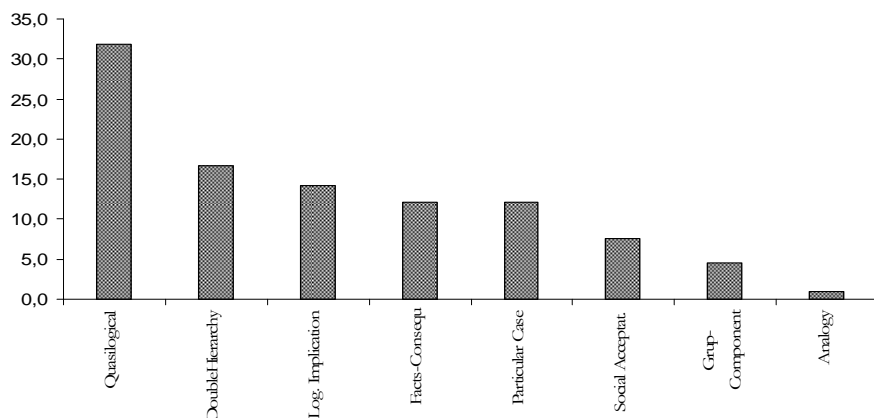


Figure 2. Percentages of types of schemes on the total number of schemes (Bristol & Bcn)

Comparing the percentages of types of argumentative schemes by tasks

We find that the types of arguments with the biggest percentages are the same in both tasks, but the order of percentages presents same differences between tasks. In the ice task the biggest percentage corresponds to the Quasilogical Based on Mathematics Relations scheme, instead, in the spit task the biggest percentage corresponds to the Double Hierarchy scheme.

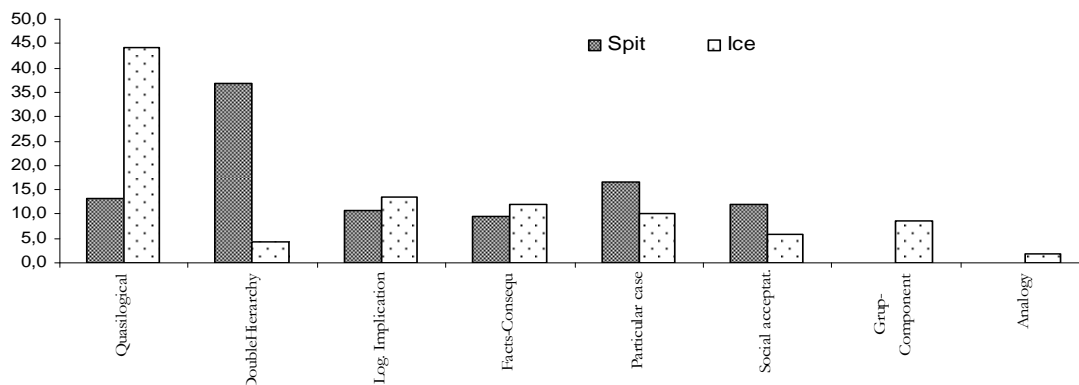


Figure 3. Comparison of percentages of types of argumentative schemes by tasks (Bristol & Bcelona)

Comparing percentages of the types of argumentative schemes by countries (Spit + Ice)

In the two separated samples (Bristol and Barcelona) we found that the order of percentages of schemes is not exactly the same, but the category with the biggest frequency coincides in both samples, this is the Quasilogical argument based on Mathematical Relations, which seems linked to an appreciation of the activities as scientific activities. There are clear differences relating the percentages of other types of argumentative schemes that we find in both countries but those are not easy to interpret (we don't include the table here), there is difficult to know if these differences are by the effect of the countries or of the tasks.

Comparing the percentages of argumentative schemes by tasks and separated countries

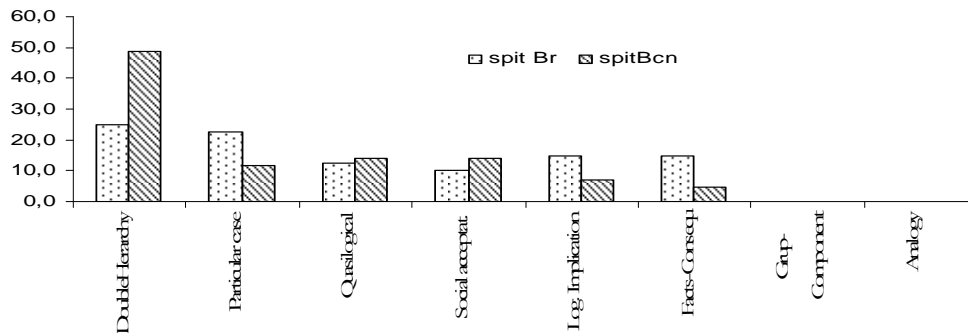


Figure 4. Percentages of types of argumentative schemes by Spit task by countries (Bristol / Bcn)

Analysing the tables of the figure 4, we found that related to the spit task although the Double Hierarchy scheme is the most frequent in Bristol and in Barcelona, the difference between the DH's percentages is bigger than the difference between the percentages of the other types of schemes, result that can be interpret as students from Barcelona answer the spit task near to the arguments the scientists use in their argumentations, using an argument that implies students reason identifying variables and supporting their arguments with their ideas about relationships between factors o magnitudes they consider are in the structure of reality.

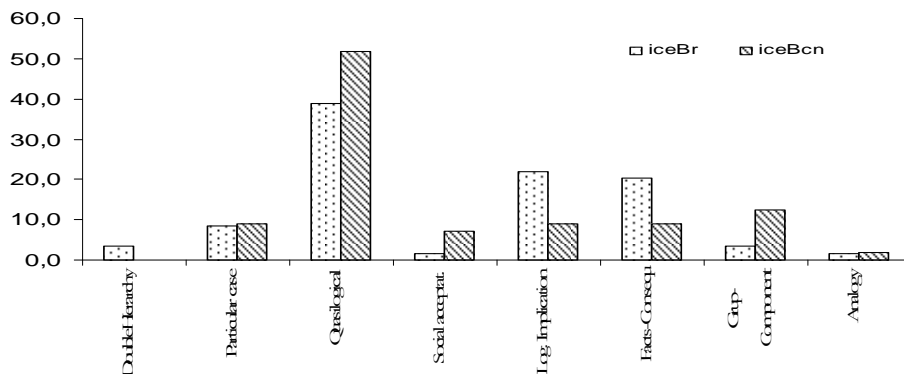


Figure 5. Percentages of types of argumentative schemes by Ice task by countries (Bristol / Bcn)

If we compare both tables 4 and 5, the global result is that there are differences in the percentages of types of schemes by tasks in both countries. For example, in the Spit task the scheme most used is the Double Hierarchy one, whereas in the Ice task the most frequent scheme, in both countries, is the Quasilogical argument Based on Mathematical Relations.

Discussion of Results

The total number of arguments and the number of arguments per minute are similar in both countries, however, there are small differences in relation to the types of tasks. The ice task facilitates to give more arguments than the spit task although the number of arguments per minute is bigger in the spit task. This result can be interpreted by the influence of the way the tasks are presented and of their content.

Related the types of schemes identified counting for the total sample, the type of schemes with the biggest percentages are into de group of Quasilogical Based on Mathematics Relations schemes. It is not a surprising result considering we proposed scientific tasks. These schemes are followed in order of percentage by the Double Hierarchy and Logical Implications. These results indicate students can identify variables in the situations presented in the tasks and that they use schemes that are near to the arguments the scientist use. But the percentages also say us that they use other types of arguments that are easy to find in not scientific contexts too, like the argument by the Particular Case and the argument by Facts and Consequence.

The differences in the percentages of types of schemes by tasks are bigger than the differences in the percentages of types of schemes by countries. For example, in the spit task the scheme most used is of Double Hierarchy one. This is an interesting result because means that students see variables and relationship between them in the spit task, as the scientist would do in other scientific context. In the ice task the most used scheme is the Quasilogical argument Based on Mathematical Relations, but among these mathematical relations the ones with the biggest percentatges are the schemes of Addition and the scheme of Compensation. This result indicates that in this activity, the reasoning of students seems be mainly by systems and elements of the systems, that means students reason by having their topological considerations as an important factor that direct the way students argue. In summary, the way students “see” globally the situations presented in the tasks is the most important factor that affect the types of schemes students use, and this is also related to the content of the task and the way it is presented.

The argumentative analysis has been very useful to constatate and to act in relation to the scientific conceptions students share in relation to those activities. In concret, in the spit task, the majority of students share the misconception that the speed of the free fall depends of the bodies’ mass. In the case of the Ice task, students accept that it is producing a climate change but the argumentative schemes, related to this specific issue, are mainly from expert opinion or authority (of media) or by examples, that can be also from media. But students, in general, share misconceptions or show a very bad scientific knowledge related to the question about floating and sinking.

There are not very big differences between students of Bristol and of Barcelona related their habilities to argue. But we find some differences related the premises used in the arguments, students of Bristol seems based more on examples or illustrations coming from the media and students in Barcelona based more on social or political ideas or values shared.

Conclusions and Implications

Results confirm the necessity to improve the knowledge of the teachers about the arguments students give commonly and especially their disposition to question their (or of the other) premises in order to foster critical thinking and conceptual change. The identification of premises and argumentative schemes favours a good understandings of the way students think and about which misconception they have. These understanding provides argumentative resources for the teacher to be used to help students to improve their scientific knowledge and their critical thinking.

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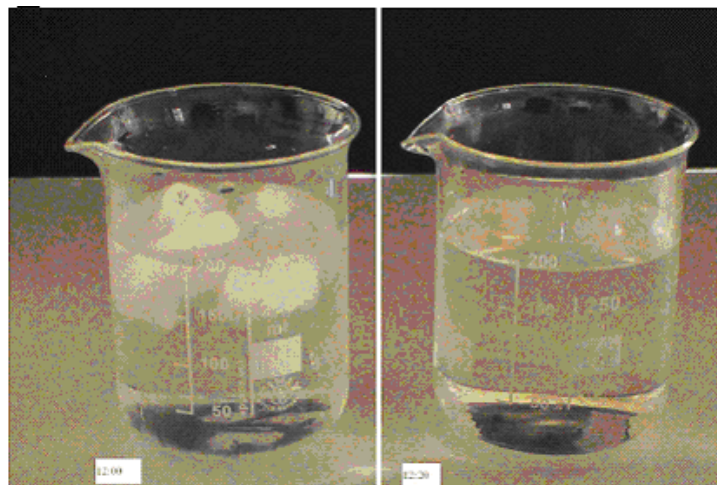
Annex:

Activity of Ice and Climate Change

1. What will happen to the level of the water when the ice melt? Why?



2. Does your prediction agree with the result we show below?



Explain the result shown in the pictures.

3. Scientifics agree that because of the increase of temperature in the Earth as the main cause of (because) the climate change, the level of the sea will increase.
Could you compare this prediction with the result of the previous experiment?

If the prediction of the scientifics is correct, how do you explain this prediction taking in consideration the previous experiment of the glass and the ice.

ARGUMENTATION AND SCIENTIFIC REASONING: THE “DOUBLE HIERARCHY” ARGUMENT

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Abstract

In the present study we have investigated junior high school students' arguments related to scientific and socioscientific issues. In a previous study (ESERA 2007) we have analysed students' arguments using theories of argumentation as Aristotle (Topics, Rhetoric), Perelman & Walton. In this way we wanted to recognise the schemes that student's arguments are based on and categorise them according the above-mentioned theories. Our hypothesis was that teachers could provide more convincing arguments to the students if they are aware not only with students' misconception but also the kind of argumentation scheme that they use when they argue their ideas. In other words, it is like a deeper way to investigate their conceptions about scientific matters. One of our results in this study was the repentance of a particular pattern that students' arguments could be included. Perelman called it as the “double hierarchy” argument. So, in this study we wanted to give a deeper analysis of this particular pattern-argument and recognise the great significance that it has among students' argumentation. Therefore, we have re-analysed several transcribed dialogues of students during several open activities in a secondary school, recognise this particular argument and find the relevance between this argument and students' scientific preconceptions. The results have showed that previous ideas of the students often follow this argument and we concern that further investigation of this relation could make us understand even better the structure of the arguments and the process of thinking. The analysis is useful both a deep understanding of students misconceptions in physics and to provide a “tool” to improve the science knowledge of the students.

Introduction

The last decades numerous studies have focused on the analysis of argumentation discourse in educational contexts, among others, Driver, Newton, & Osborne, 2000; Duschl, 1999; Jimenez-Aleixandre, Burgalló & Duschl, 2000; Kelly & Takao, 2002; Erduran and Jimenez-Aleixandre, 2008. Great influence of this significant attention has been contemporary's theories of argumentation. Especially Toulmin's, who apart from the theoretical part of his work, has provided with his schematics representation of arguments, which has been a useful and practical tool to analyse the arguments made by the students. The new approach of this work is to use the argumentation schemes as an instrument to understand the ideas and conceptions of students through the analysis of the structural part of the arguments and identifying in which schema the argument is based on. With our proposal, the misconceptions of the students, that of course, has taken part of numerous studies the last decades in the field of science education and physiology, could be re-analysed with an argumentation focus approach. In this way, we could be capable to characterise and identify the kind of arguments that are used mainly by the students and to understand better the difficulties of the conceptual change widely discussed in science education.

From previous research about student's scientific ideas and conceptions, we know that regarding many previous ideas in physics it is difficult, even with demonstration, to make students understand and accept the scientific theory. In the present study we investigate junior high school students' arguments related to scientific issues. We base our study on different argumentation theories because each of these theories was elaborated with the purpose to serve a particular context. We use argumentative schemes of Perelman (1958), Hastings (1963?), Walton (1996, 2006) and also from the two works of Aristotle (IV b), Topics and Rhetoric. According those authors when people argue elaborate arguments, a single argument is made of several premises, a thesis or conclusion and the argumentative scheme that allows and justifies the transference from the premises to the conclusion or thesis. None of these argumentation theories are made to serve the discourse analysis in an educational context. So, one of our purpose is to see the particular need of this context and build an analytical framework, based on these theories, capable to help us understand students' reasoning in scientific issues. The synthesis of these schemes might be a useful tool for future researches in argumentation in an educational context, in order to understand better students' ideas and misconceptions. Our hypothesis was that teachers could provide more convincing arguments to the students if they are aware, not only of the previous ideas of the students, but also the kind of argumentative scheme that they use when they argue their ideas. One of our results in that study (Castells, Erduran & Konstantinidou, 2008) was the repetition of a particular pattern, which could include several students' arguments that are present in different situations. Perelman (1958) named it as the "double hierarchy" argument.

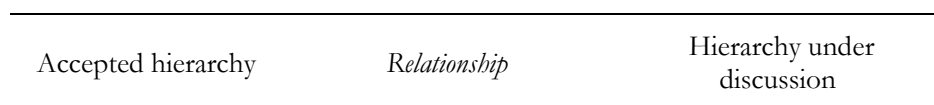
In this study we want to do a deep analysis of this particular pattern-argument of Double Hierarchy (DH) and recognise the great significance that it has among students' argumentation.

Rationale

As we mention before, analyzing the different arguments, we have found an argument that was repeated quite often. The purpose of this paper is the focus on the structure of this argument, not only for its repetition but also for its relation with some student's misconceptions.

In the DH argument (Perelman, 1969), arguers use the DH strategy when they take an established series or hierarchy, one accepted by, or at least familiar to an audience, and form a second series on the model of the first, in the process trying to transfer implications of order or value from the first to the second. The goal of the DH argument is to make a second ordering possible and plausible. For example mediaeval alchemists ordered the seven known metals by the hierarchy of the seven heavenly bodies, equating gold with the sun, silver with the moon, and so on (Jeanne Fahnestock, 1999). According Perelman (1958), DH arguments are based on liaisons either of succession¹ or of coexistence² and can be classified among the arguments based on the structure of reality, which are arguments that are based to the nature of things themselves. With this kind of argument, a hierarchy is argued from other hierarchy by a correlation between the terms of one and of the other. The DH usually expresses a relationship of direct or inverse proportionality or at least a link between the parts of each hierarchy. Arguments of double hierarchy could be interpreted many times by the combination of a scheme of cause and effect, or other type of relation, and a scheme of more -> more, and this gives to this type of argument a very interesting inclusive character.

The DH scheme has at least three parts. The hierarchy under discussion, (many times is the hierarchy that we are arguing), the accepted hierarchy (the hierarchy that we based our argument and that correspond to our ideas about the real world) and the third part is the relation that we establish between the two hierarchies.



¹ Sucesión linkages

² Coexistence linkages

Summarising, the scheme of DH is based on the argumentation of a hierarchy that is under discussion, using a hierarchy that is accepted. The hierarchies could be quantitative or qualitative. We have found hierarchies of both types in our analysis. Important part of the DH argument is the relation that students establish between the two hierarchies. Many times, it expresses a proportional or non-proportional relation between the elements of the two series.

It is very essential to define very clear the above three parts. Knowing the procedure of analysis of an argument can help us understand better the misconception that is related to this argument and see where it is mistaken. In this way, the teacher is better prepared to counter argue the arguments of the students. According the argumentation theory, the DH arguments can be refuted by three ways:

- Denying the correctness of one of the hierarchies
- Denying the relation between the two hierarchies
- Opposing a different DH from the first presented and by this way the necessity to change it.

The first refutation type implies a miscomprehension of the quantitative or qualitative values of the hierarchies. The second case of refutation indicates a change of point of view on the structure of reality that has been proposed as the base of the DH. The last type of refutation, introduces a point of view that the students didn't take into account. It also modifies the structure of reality, engaging more aspects of the complexity of the situation, showing that the first aspect was too simple. This new perception is not only pure new knowledge for them, it is their own modified knowledge, in other words a more complex vision of their own perhaps limited point of view. Another interesting point of the refutation procedure is the role of the experiments in this process, especially in the quantitative DHs. One may think that the experiment is by itself a sufficient and definitive argument. We think that the experiment needs to be part of the argumentative procedure of refutation and the convincement of the other. So, it is necessary that students explicit their arguments in detail and by this way the experiment could be integrated to the refutation of the arguments of the students.

Methods

This is a qualitative study where the major objectives of the research were to identify the students' arguments and then relate these arguments with their prior conceptions in domains relevant to science and specifically in physics.

Subjects

All 15 students who participated in this study were primary pre-service teachers in the University of Barcelona. The scientific background of these students was quite limited in science topics. These students were distributed in four groups.

The activities

The two open activities (Appendix A) were given to all the groups. Students were asked first to do the task individually, writing down their answer, expressing their point of view. After completing this part, they had to discuss their own answers with the rest of the group and try to find a solution to the problem.

Written individual answers and the discussions of 4 groups to the two activities on physics were collected and transcribed, then they are analysed and in them double hierarchy argumentative schemes are identified. We observe the structure of these specific arguments and its relation with previous ideas in science.

Results

Before entering with more details to the results of this study and the presentation of examples of the DH argumentation scheme, it would be wise to considerate that many arguments are not very clear explained and that their interpretation could be with more than one argumentation schemes. This situation makes more difficult the argumentative analysis because many times we could interpret different possible argumentation schemes in the students' interventions

Students' responses and transcript discussions were analysed. First by trying to identify the different arguments of the students and then isolate the particular pattern of DH argument that we focus in this study. We have found DH argument to most of the discussions, which means that in activities with topics as free falling and floatability, this type of argument is applied and it is a rather common argument. Once one double hierarchy argument is identified, its structure is analysed.

Examples of the DH argument

Activity 1

Here we present the most typical students' arguments with a proposal of refutation. For example one student wrote:

Marta: "I thought that **this could happen** because I thought that if a man is heavier than his spit or vomit he could ... he would fall quicker"

In this argument we can identify two hierarchies. The hierarchy that is under discussion, in this case is the velocity of the spit, in other words the spit have less speed from the man that has more. The accepted hierarchy is the weight of the spit and the man. It cannot be questioned that the spit weights less than the man. The relation between the two hierarchies in this particular case is the proportionality that students consider between the speed and the weight.

Table 1. Example of DH argument (activity 1)

Accepted hierarchy	Relationship	Hierarchy under discussion
Weight -spit → +man	The velocity is proportional to the weight	Speed -speed → +man

In this example the hierarchy of weigh is undeniable and the speed hierarchy could be denied experimentally but first we would like to search for argumentative resources. So, we can use the third refutation type and oppose a different hierarchy between the weigh (mass) and the velocity. The bigger the mass of an object is, and thus the weight, the lesser the gain of speed when we apply a force to it. This hierarchy is familiar to the students; from their own experience they know that an object of a greater mass is more difficult to be displaced. By combining the two DHs, we can have an argument of compensation in such a way that the two effects are compensated and perhaps we might contribute to change their ideas about free falling.

More weight	→	more speed
More mass	→	less speed

Another type of refutation could be the following. In the case that the students have expressed in their arguments a direct proportionality between weight and speed, a second type of refutation is possible. In order to deny the relation between the two hierarchies a possible refutation might be, ask the students what would have happened with two balls that the one has the double mass than the other. After their prediction, the realisation of the experiment wouldn't confirm the prediction, so we would have a counter-argument that denies the suggested relation between the two hierarchies of weight and speed. It is quite obvious that it's not inconvenient to use different types of refutation. The combination of different arguments of refutation could make stronger the convincing value of the arguments and change the point of view of reality of the students.

Form the above refutation procedure, we might use the metaphor that performing the whole procedure is like performing an intervening operation to a patient, which is our wrong argument, after making the diagnosis with medical scanner, which is the DH argument structure.

Activity 2

Following the same methodology with the fist activity, we gave the students the second one (APENDIX), which was about floatability. The main question was why the raft had sunk, and what we could do to avoid this situation. A great part of the students argue this situation using the DH between different size surfaces that is in contact with the water with the weight that the raft might support. We present here the most typical arguments of the second task:

Transcript: Paul: "The surface of the raft in comparison with the mammoth is not extensive enough to allow the water to support the mammoth. (...). If the raft had a much larger area than now, this does not happen".

Anna: "... the surface of the raft is not sufficient to support the weight of the mammoth on the water. (...) Our solution is to increase the surface of the raft on contact with water (length and width), but not in height. The more surface has the raft, more weight is able to withstand the mammoth, and the greater the force that causes the raft on the water "

In Paul's explanation, there are two variables in his argument; a quantitative one that is the size of the surface of the raft, and a qualitative notion with only two opposite values, which is in this case the capability of the raft to support or not the mammoth. So, the DH hierarchy that we face here is a type of opposite sides DH, in which the hierarchy under discussion consists of two opposite qualitative situations. The accepted hierarchy of more or less surface permits the student to establish the hierarchy of support or not support capability of the raft, which could be in discussion. In this way, with the present used surface the mammoth cannot float, but with a biggest surface the raft with the mammoth might float. The relationship between these hierarchies is a means (surface) /ends (support, not support) type of relation.

Table 2. Example 2 of DH argument (activity 2)

Accepted hierarchy	Relationship	Hierarchy under discussion
Surface -→+	means/ends	Support or not support

In Anna's explanation we have the two series of hierarchies both with a quantitative value. The first is the surface of the raft and the second is the weight that the raft can support in order to float. The relation between the two hierarchies is the same the previous example, the means (surface)/ ends (support the weight) relation. In this second explanation, it is not clear the role of the water in this situation.

Table 3. Example 3 of DH argument (activity 2)

Accepted hierarchy	Relationship	Hierarchy under discussion
Surface -→+	means/ends	weight

Both of the two above arguments try to explain that the phenomenon of floatability is related to the extension of the surface. In the first example, we have only one variable, since the second one is a qualitative notion. In that answer, is not clear the role of the water in this situation, so we could make a first comment to students by explaining to them that the water is what supports both the raft's and mammoth's weight. So, after this observation, the situation of the two above arguments is similar and can be refuted using the same way.

1. First of all we can observe that the DH argument has an obvious problem with the relationship between these two hierarchies. According to the above-mentioned ways to refute a DH argument, in this case is recommendable to deny this relation introducing an experiment (second type). For example we can use a piece of “play dough” putting it into the water, once in a form of a cube, and once in a form of an empty cube. So, we can show them that the relation of the floatability with the area of the surface is not correct.
2. The second phase of this DH argument refutation consists of introducing the correct first hierarchy's value (third type of refutation), which is the concept of volume that determines the weight that the raft can support. This can happen again introducing to the argumentation procedure another experiment. We can use, for example, a square made of cork that floats and we keep putting different masses above it. We can observe that meanwhile the surface in contact with the water is the same; the volume of the submerged piece of cork is getting bigger with the bigger mass that needs to support. In other words, the height of the cork that is each time is submerged into the water; in order to support the different weights is different. The heavier the object, the grater is the length of the submerged cork. The combination of these two variables are related with the weight that the cork can support, the surface and the length of one of the dimensions of the cork can take us to the idea that the variable submerged volume is what determine the weight that the cork can support. In summary, the combination of these two experiments can modify the argument toward the scientific point of view, by changing the concept of surface with the concept of submerged volume.

Conclusions and Implications

From the results we confirm our hypothesis that the analysis done is useful both a deep understanding of students misconceptions in physics and to provide a “tool” to contribute to change the incorrect reasoning or ideas and to improve the science knowledge of the students. In fact, the knowledge of the “double hierarchy” structure can be a help for teachers to attack the arguments and so the conceptions of students using the same argumentative scheme the students use themselves and making clear their structure to them.

An implication for this study could be suggestions to introduce the argumentation schemes and especially the DH argument in the process of teaching. So, from problematic situations like, for example, the above activities, the students explain their ideas using argumentative schemes as the DH argument. So, the teacher could insist through a dialogical process, that students need to explicit their arguments. With teaches' synthesis of the different arguments that came out, different refutations can be guided from both sides to find the correct counter-arguments. The final outcome of this procedure could be writing down a text with their first idea and explain why this ideas is the same or different with the final idea of the discussion with the teacher. May be in the future, we can present results of this didactical approach, that show the promising character of using argumentation in a science class.

A deep understanding of the double hierarchies contributes to group previous scientific ideas of students, the knowledge of these groups and of their common scheme by the teachers is necessary if they want to persuade students of the scientific ideas.

On the other hand, by studying and recognising the argumentative schemes in general and particular the DH argument that are used in the students alternative ideas about science, we can better understand the procedure of arguing by identify the different parts of the argument and perhaps relate this arguing procedure with the learning process of the student.

To conclude we can point out that it is true that argumentation theories are not made to analyse arguments in a science context. But we have seen that their argumentative schemes could be a very useful tool to persuade the students and try teachers to find more convincing arguments. Also, a very interesting point that we have not treated until now is the significance of being able to identify and modify arguments to the critical thinking improvement of the students.

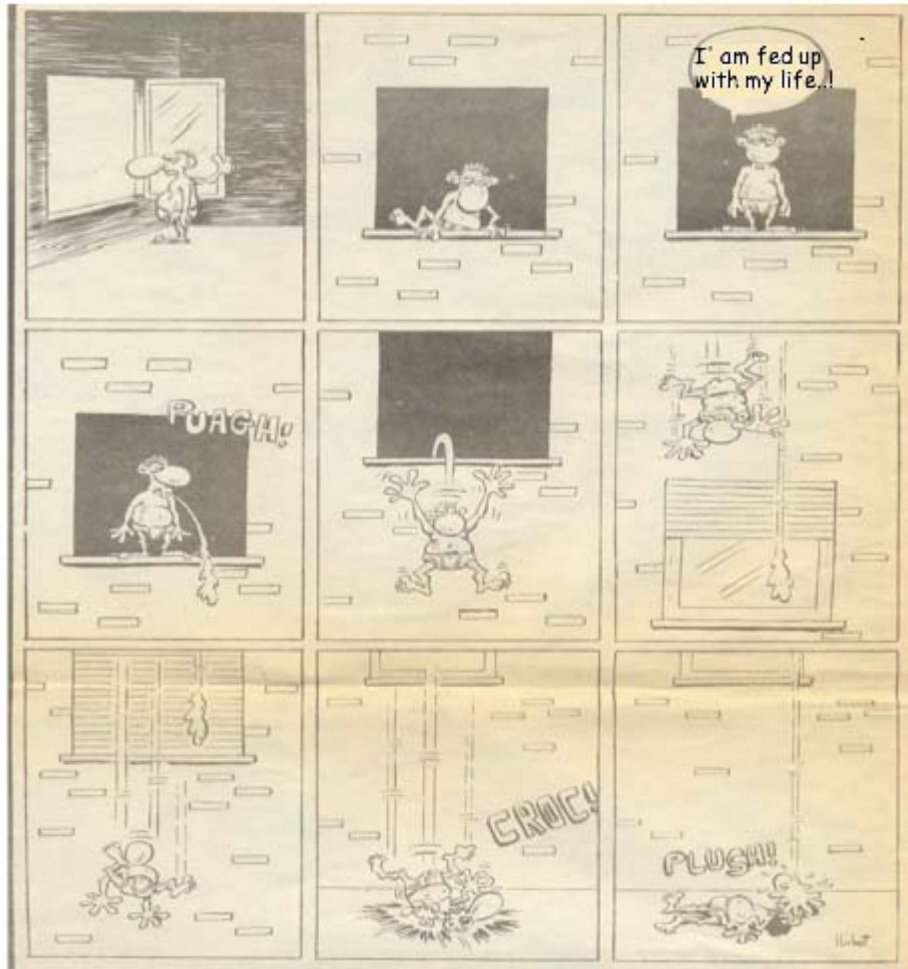
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APENDIX

Proposed activity 1:

They students had to argue if the situation that is given to the comic below could happen in reality.

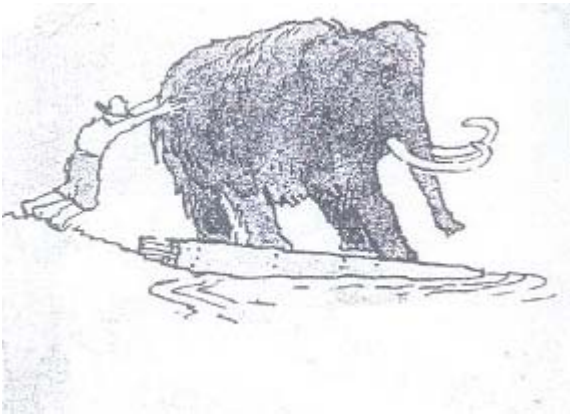


Proposed activity 2:

Floatability

Read the following story and imagine that you are the narrator.

THE TRANSPORT OF THE MAMMOTH

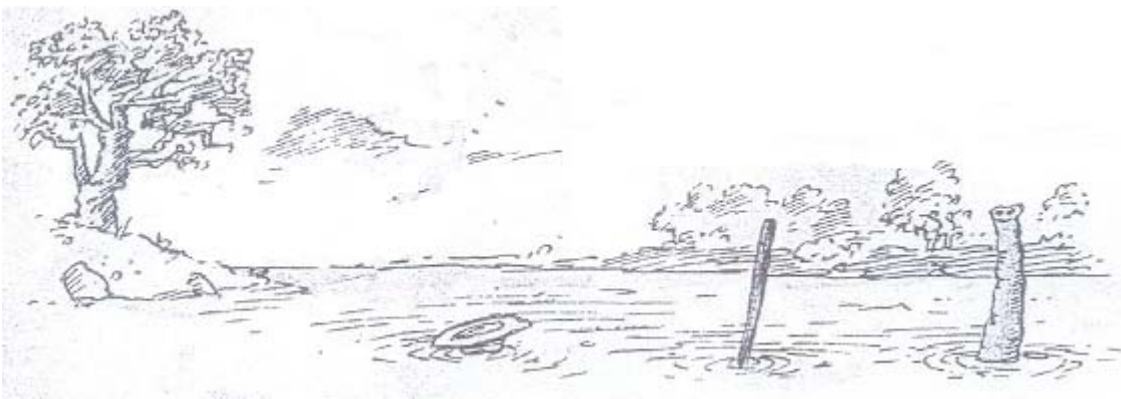


Once, while I was waiting to get into the ferry, I saw that an operator from a rival company in another part of the shore of the river was trying to force a big Mammoth into a plain boat that was roughly of its size. Just when the loaded boat slipped onto the water, it sunk down.

I was astonished when I saw what happened, and I got out of the boarding queue, in order to try to help. My help was immediately accepted by the wet operator and the Mammoth. After making some questions to the people implicated in what happened, I made a few calculations and I deducted that the spirit of the water was frightened by the weight of the loaded boat and that it moved away from it, that is to say, no water was left under the boat and thus the

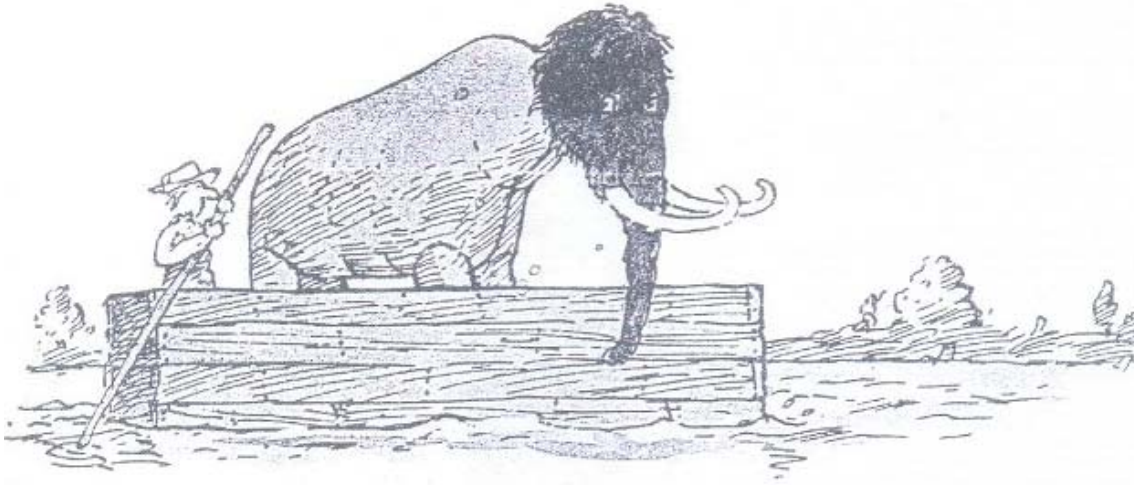
boat sunk.

It was pretty clear that some sort of trick was necessary in order to keep the load floating. Then I advised to hide the Mammoth from the spirit of the water, using a special invention of mine.



1). What would you advise to the operator to do in order to be able to transport the mammoth from one side of the river to the other safely?

The narrator of the story proposes the following solution:



I achieved my purpose. All around the plain boat we added a wooden fence and, surprisingly for everyone except obviously for myself, the loaded boat was floating on the river with no problems.

- 2). Do you agree with the solution proposed by the narrator? Explain your answer.
- 3). If you disagree, propose an alternative solution and justify, using your scientific knowledge, your personal experience or what you have read.
- 4). Share your proposed solutions and try to get an agreement about which of the solutions is the most adequate. You have to do it by presenting and discussing the arguments that each of you has for their solution and the counter-arguments for the solutions of the others.

THE QUALITY OF STUDENTS' ARGUMENTATION AND THEIR CONCEPTUAL UNDERSTANDING – AN EXPLORATION OF THEIR INTERRELATIONSHIP

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Abstract

The research project aims to investigate how the quality of students' argumentation depends on their conceptual understanding and vice versa. Data analysis is based upon two different theoretical frameworks: A refined version of Toulmin's argument patterns is used to describe the processes of argumentation and its quality. Students' conceptual understanding is investigated with a coding schema distinguishing between exploration, intuitive rule-based understanding and explicit rule-based understanding. Video data from students of different age working in groups on physics and biology instruction were analyzed with these two frameworks. Results demonstrate that each single argumentation typically contains only few different elements, and elements that are regarded to be of "higher quality" are rare. Argumentations that consist of high structural and high conceptual quality occurred when students were able to utilize everyday-experiences or specific experiences they made during the learning sequences.

Rationale

Science educators argue that argumentation is an important aspect of science education in general, and that argumentation promotes the learning of the science content (e.g., Zohar & Nemet, 2002). Conversely, research indicates that students' ability to argue is limited by their content specific knowledge (e.g., Means & Voss, 1996; Sadler, 2004). But research rarely explicitly addresses (details of) the interrelationship between argumentation and conceptual understanding. Research reported in this paper aims to explore the interrelationship between students' argumentations and their conceptual development. In particular, we want to investigate how the quality of students' argumentation depends on students' conceptual understanding and vice versa. Therefore, the project explores the following research question:

What kind of interrelationship can be determined between the quality of students' argumentation and their conceptual understanding of the topic given?

Methods

In order to explore the interrelationship between argumentation and conceptual development, learning material was developed which aimed at both aspects. Referring to the model of Educational Reconstruction (Duit, Gropengießer, & Kattmann, 2005), four teaching sequences were developed concerning blood pressure, heat transfer, electric circuits and light & shadow. Each sequence comprises two sessions of about 160 minutes in total. The two sessions were subdivided into three phases: The first phase consisted of instruction aiming to establish an understanding of the phenomena which is discussed in the argument-task. The corresponding task was taken from material developed at King's College London (e.g., Osborne, Erduran, & Simon, 2004) and presented in the second phase. Finally, the last phase consisted of instructions addressing the contents which were deployed in the arguments task. All units developed were tested by a sample of 28 students from university who were working in groups of two to three students on one of the units. These students were studying social sciences and did not have a strong background in the topics covered by the units. Videoing of the processes informed us about necessary changes (such as for instruction that was not understood or experiments that did not work as expected). The main study consisted of two samples: 18 students from grade 8 (about 13 years old) and 12 students from grade 11 (about 16 years old). The students worked in groups of three on two out of the four topics. All activities were recorded on video. Data analyses have been based upon two different theoretical frameworks: A refined version of Toulmin's argument pattern (Toulmin, 2003) is used to describe the processes of argumentation and its quality (v. Aufschnaiter et al., 2008b). Our inter-coder agreement usually exceeds 80 % between different raters (cohens kappa between 0.6 and 0.75). Students' conceptual understanding is investigated by a schema which distinguishes between exploration, intuitive rule-based understanding and explicit rule-based understanding (only the latter would be referred to as being "conceptual") (for more details see v. Aufschnaiter, 2006).

Results

Structure of argumentation

So far, we have analysed all sessions from heat transfer and electric circuits, and four sessions from blood pressure leading to in total 419 identified argumentations spread over the sessions. Results demonstrate that each single argumentation typically contains only few different elements (Figure 1a). For instance, 25% of students' argumentations investigated so far are built of a claim and one datum and 18% consist of a claim and a counterclaim without any further justifications (all these argumentations are relatively short). Combinations including elements other than claim, counterclaim and data are rare which can be seen in Figure 1b. Nearly all argumentations contain a claim (which is expressed by a frequency being almost 100%), in 53% of all argumentations investigated at least one counterclaim is formulated. In contrast, elements like warrants are only present in 3% of all argumentations.

In addition to focusing on all argumentations no matter of the units' content, we have also compared the occurrence of each element in students' argumentation within each unit (Figure 2). Even though the students developed less counterclaims during the learning sequence of electric circuits there are only small differences between the units.

By comparing the frequency of elements in students' argumentation during the different phases of the learning sequences results demonstrate only small differences (Figure 3). This means that even though the argument task in phase II explicitly prompted students to argue the students did not develop elements that are regarded to be of higher quality more frequently than without an explicit stimulation.

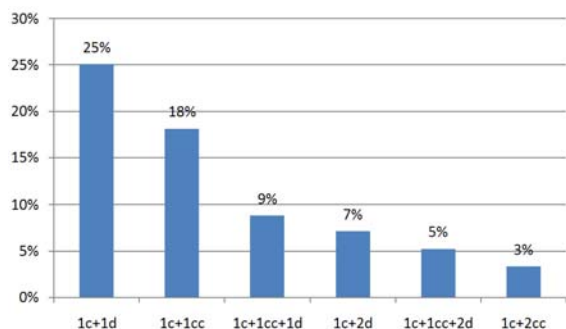


Figure 1a. Frequency of argumentations consisting of particular combinations of elements (results based on 419 argumentations taken from the sequences on blood pressure, electric circuits, and heat transfer)

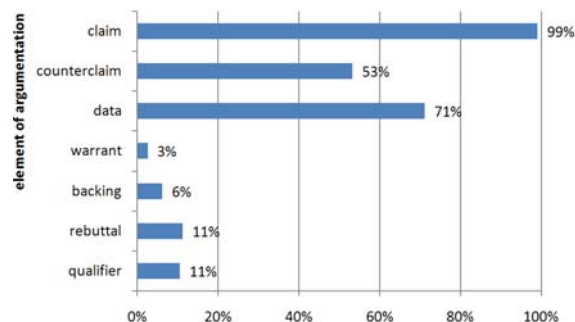


Figure 1b. Occurrence of each element in students' argumentations (results based on 419 argumentations taken from the sequences on blood pressure, electric circuits and heat transfer)

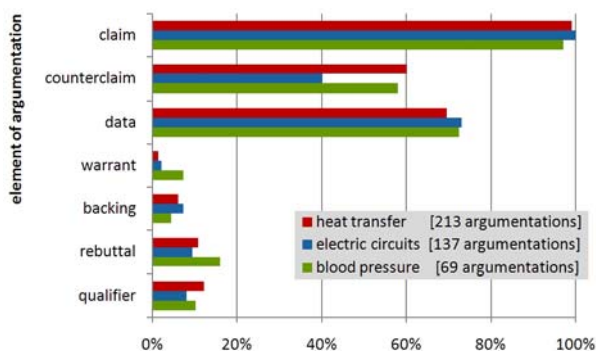


Figure 2. Occurrence of each element in students' argumentation during the different learning sequences (results based on 419 argumentations taken from the sequences on blood pressure, electric circuits and heat transfer)

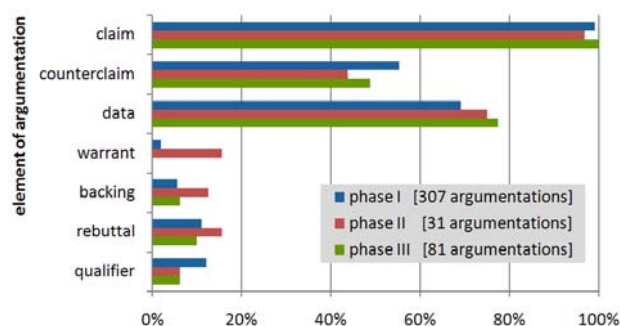


Figure 3. Occurrence of each element in students' argumentation during phase I, II and III of the learning sequences (results based on 419 argumentations taken from the sequences on blood pressure, electric circuits and heat transfer)

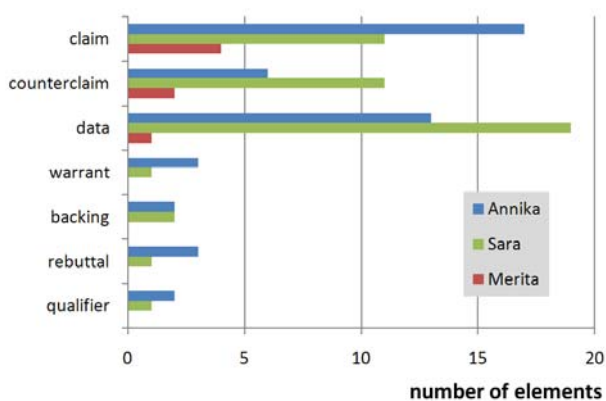


Figure 4. Number of elements employed by each group member into the group's argumentations (numbers based on 35 argumentations taken from the sequence on blood pressure)

In addition to our data analysis concerning the frequency of elements employed into students' argumentation, we have also compared how often each group member contributes to an argumentation and which element is used. For instance, for a female group from grade 8 (Figure 4) it is obvious that Merita rarely whereas Annika quite frequently formulates the claim. Sara in contrast offers data very often. Elements of higher quality are, in this group, only developed by Annika and Sara. Similar results can be found in all learning sequences and for all groups, no matter of their age and gender.

Conceptual knowledge

Conceptual knowledge has been analysed so far for all groups participating in the sequence on heat transfer and for two groups working on the sequence on blood pressure. Our analyses of these groups show that students mainly construct knowledge which is explorative or intuitive rule-based in nature. Comparing the conceptualisations of grade 8 and 11 (see the example given in Figure 5) reveals that the older students express (significantly) more intuitive rule-based knowledge and slightly more explicit rule-based knowledge than the younger ones. However, it should be noted that not only for this example but also for other groups, variances are high in-between groups.

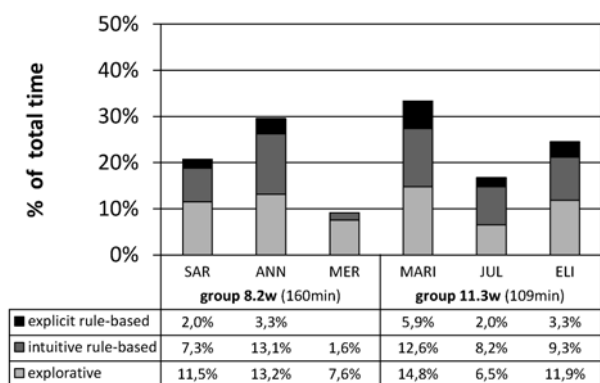


Figure 5. Example of two groups' frequency of conceptual knowledge expressed by each individual group member in relation to the total time of the learning sequence on blood pressure (in brackets)

Argumentation and conceptual knowledge

Students that were able to develop an explicit rule-based understanding used more often elements of argumentation that are regarded to be of higher quality (like Annika, see Figure 2 and Figure 3). Even though we were not yet able to identify a systematic interrelationship between the structural quality of students' argumentations and their conceptual understanding, a more detailed analysis of students' argumentations revealed how dominant students' experiences are. Typically, argumentations that consist of both a high structural and a high conceptual quality occurred when students were able to utilize everyday-experiences or specific experiences they made during the learning sequences. However, it should be noted that the way in which students conceptualized some aspects was not intended by the learning material and is scientifically not appropriate. This issue is demonstrated by the following example which is taken from the sequence of blood pressure. Here, a group from grade 8 discusses their ideas about the colour of arteries and veins:

Transcript	TAP	Conceptual level
Annika: I got it: Probably, arteries are warm and veins are cold. / Therefore, arteries are typically coloured red and veins blue. / These colours refer to warm and cold. And the arteries carry the heat into the finger tips. And then the coldness has to go away, and the veins take along the coldness.	claim data 1-4	explicit rule-based (conceptual)
Sarah: In spite of this, I don't get warm.	rebuttal 1	Intuitive rule-based
Annika: Anyway, your finger tips stay warm for a long time.	rebuttal 2	Intuitive rule-based

Transcript 1. Students' argumentation about the functions of veins and arteries

In the further sequence of transcript 1 the students were asked to decide between different reasons why everyone's face gets redder while exercising (argument-task). Even though being taught about the different aspects of blood circulation, hardly any group who was working on the sequence about blood pressure discussed four theories offered in an appropriate way in order to identify the scientific explanation ("Your blood gets closer to the surface for excess heat to be lost"). Rather, this group of grade 8 students as well as almost all other students interpreted "pressure" in terms of their everyday experiences of "pumping" which they feel when their pulse increases (transcript 2).

Transcript	TAP	Conceptual Level
Annika: If you have more [blood], the arteries expand. They expand because there is more pressure and, thus, the surface of your skin gets redder. / The blood pressure increases and then more blood is pumped through, and then everything expands, and then there is more blood and it looks redder.	warrant repeats warrant	intuitive rule-based

Transcript 2. Students' argumentation about why the skin gets redder while exercising

Conclusions and Implications

The project aims to shed (more) light into the debate on how argumentation and conceptual understanding interrelate. Such an understanding would improve both, the teaching about science and the teaching of science. At first sight, our results seem to be disappointing: Our students did not often argue at a high structural level, nor did they explicitly develop a conceptual understanding very frequently. However, it can be noted that the students argued even though they were not prompted to do so (during the "preparation phase") and they had not received an instruction on how to argue. Therefore, these students were able to construct argumentations by themselves which can be regarded as a promising result. Also, mean engagement and over all active participation in our sequences was (much) higher than in a typical science classroom. The high variances of individual contributions to an argumentation and of individual frequency of conceptual knowledge, even within the same grade, are one important result as well. It points to the need to understand better what causes these differences and how learning material and tasks prompting students to argue need to be adapted accordingly.

From our results we would conclude that it is not very likely, especially for complex scientific issues, that students will and can address scientific ideas in their argumentation. Rather, they are very likely to engage with everyday experiences (see also v. Aufschnaiter et al., 2008a). Although this may lead to argumentations of higher quality (in terms of both their structural and their conceptual level) these also show a limitation which might have at least two consequences: a) promoting students' argumentation in school science settings will need a large number of appropriate experiences in order to enable students to engage with scientific concepts (rather than with everyday experiences) and b) any formal training on argumentation may only result in limited competencies to engage in actual scientific debates as this engagement (again) requires a large number of content specific experiences.

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METHODS FOR INVESTIGATING STUDENTS' LEARNING AND INTERACTION WITH A HAPTIC VIRTUAL BIOMOLECULAR MODEL

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Abstract

Although immersive haptic virtual technologies are emerging rapidly in modern education, few methods exist for delivering data on the pedagogical merits of such models in the molecular life sciences. This paper reports on a selection of methods that we have used to obtain and analyse data on students' learning and interaction with a haptic virtual model of protein-ligand docking, previously designed by author PBP. The methods have been developed and employed in a university setting where the model has been used during advanced biomolecular interactions courses. In this regard, we present data-collection methods that include written items, interviews, think-aloud tasks and automated time-stamped logs, and corresponding quantitative and qualitative analytical procedures such as pre/posttest comparisons, word usage analysis, and visualized profiling of students' interaction with the model. Our results suggest that these methods are useful for generating valuable information on students' learning gain, changes in conceptual understanding, reasoning processes and patterns of interaction with the model. Dissemination of such methods could provide an empirical contribution to the dearth of research instruments in this domain. Future research will develop these methodologies to explore the relationship between using the model and students' conceptual and embodied learning.

Introduction

Other than perceiving information visually and aurally, recent virtual environments (e.g. Reiner, 2004) engage a user's haptic sense, which is the perception of touch and force stimuli such as texture, hardness and shape (Lederman & Klatzky, 1987). The haptic modality integrates kinaesthetic and cutaneous sensory input, allowing for exploration of the immediate surroundings through active touch (Klatzky & Lederman, 2002). Haptic experiences have been exploited in human-computer interaction technology so that users can feel and manipulate virtual objects that exist in 3D space (e.g. Srinivasan & Basdogan, 1997). While such environments show great promise for education, little science education research has considered students' learning and interaction with haptic virtual models (Minogue & Jones, 2006). Furthermore, work on haptic virtual models in the molecular life sciences has largely concerned usability and evaluative dimensions (e.g. Martin, Eid, & El Saddik, 2008) and hardly any empirical inquiry has focused on uncovering cognitive and learning aspects underlying users' interaction.

For the last five years, our group has been concerned with obtaining information on students' learning about biochemical interactions, and in particular, protein-ligand docking (e.g. Bivall Persson et al., 2007). The molecular processes of living systems are highly dependent on proteins and their capacity for molecular recognition, and it is thus of critical importance for students to understand the concept of docking. This pertains to the physical process during which a ligand molecule (often a relatively small molecule) and a protein in solution come into proximity of each other and interact favourably, eventually forming a complex in which the ligand binds to an area of the protein surface. Individual non-covalent intermolecular forces are transient in solution, but strong binding between a protein and a ligand is made possible by cooperative reinforcement of several simultaneous weak interactions. At a conceptual level, protein-ligand docking represents the intersection of at least three important perspectives of

molecular life science: the dynamic nature of biomolecular systems, the nature and geometric dependencies of non-covalent intermolecular interactions, and the importance of chemical and sterical constraints in systems involving macromolecules. With respect to the construction of these concepts, our group's work has been focused on investigating learning with a virtual haptic model developed by author PBP.

Rationale

Description of the haptic virtual protein-ligand docking model

The bimodal system developed by Bivall Persson et al. (2007) incorporates 3D stereo graphics and force feedback to represent the docking process. A haptic device is used to manipulate the ligand, while a simultaneous force output is delivered as the ligand is moved close to a protein (Figure 1, right). The force acting on the ligand, and correspondingly perceived by the user through the haptic sensory channel, is calculated by the system using the protein's potential field and the molecular structure of the ligand (see Bivall Persson et al., 2007). Thus, the force acting on the ligand during docking is determined by the local environment in the protein's potential field. This corresponds to the sum of the energetic potential field gradients for the ligand atoms, according to equation 1.

$$F_{ligand} = \sum_{i=0}^n -\nabla\phi_i(x_i) - q_i\nabla\phi_{esp}(x_i) \quad (1)$$

Where n is the number of atoms in the ligand, i denotes each individual atom, and q_i is the charge on atom i . $\phi_i(x_i)$ is the potential field that is specific for the species of atom i , while $\phi_{esp}(x_i)$ is an electrostatic potential field. The force calculated from the potential field surrounding the protein is scaled to be perceptible by the human haptic sense, and presented to the user through the haptic device. Several docking systems that incorporate different protein types and corresponding ligands can be explored with the model, which can be visually rendered in several representational modes (e.g. Figure 1, left).

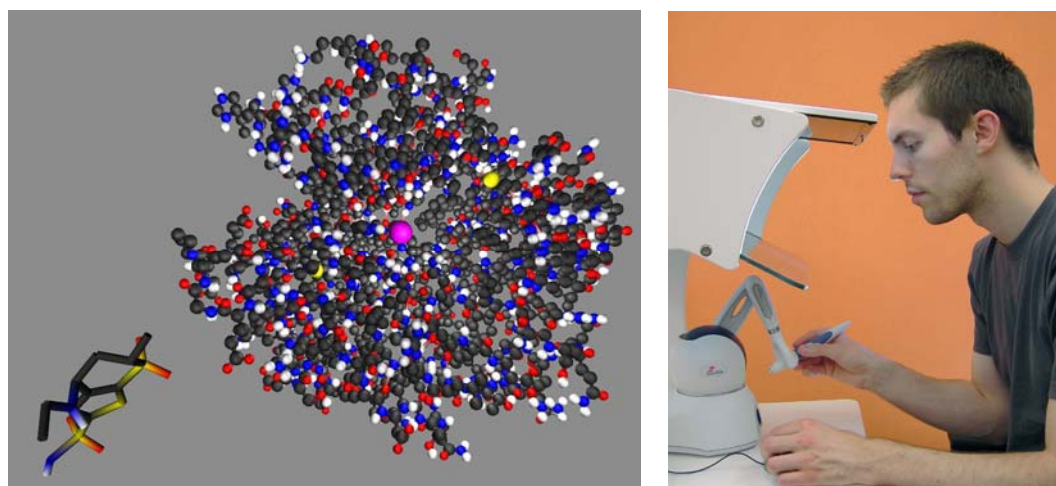


Figure 1. Left: Screenshot showing ligand (small molecule) and protein (large molecule) from one docking system. Right: Photograph of a student using the hardware that renders the haptic virtual model.

Research purpose

Although haptic technologies offer exciting pedagogical promise, few empirical methods exist for explicitly investigating students' learning and interaction with haptic virtual models in the molecular life sciences. The haptic virtual model described above has been used during advanced biomolecular interactions courses offered at Linköping University, Sweden, with classes ranging from 9 to 23 students. Generating any useful information concerning the benefits of such models in real educational contexts requires suitable data-gathering and analytical

methods to measure their role in learning and understanding. It is our opinion that this endeavour should involve obtaining a combination of ‘before and after’ as well as ‘moment-by-moment’ data. Based on this motivation, the purpose of this paper is to present a selection of methods that we have developed to respond to the following questions:

- How can students’ learning outcomes be measured after interaction with the model?
- How can changes in understanding be identified and characterized?
- How can real-time interaction with the model be monitored?

Methods for Investigating Students’ Learning and Interaction with the Model

How can students’ learning outcomes be measured after interaction with the model?

In presenting examples of methods that have yielded empirical results, a selected written item that was used in two pre/posttest studies during separate years (termed study 1 and 2 in this paper) was as follows:

Describe the process of a substrate coming into and finally binding in the active site of an enzyme. Imagine that you are sitting on the substrate, describe everything that happens on the way in, until the substrate has bound.

Student responses to this item were scored against a list of possible acceptable answers constructed by two biochemistry educators. Here, several important protein-ligand docking principles (e.g. complementary fit and intermolecular dynamics) were used to collate a set of scientific propositions that represented acceptable answers. Upon using this scoring scheme, the agreement between the assessors on students’ responses to the above item was 85%, indicating a favourable inter-rater reliability. Any gain in learning after interacting with the model (with haptic feedback enabled or disabled) was measured by comparing students’ pretest and posttest scores (Table 1).

Table 1. Comparison between students’ pretest and posttest mean scores.

Group	Pretest (%)	Posttest (%)
Study 1 control (haptic feedback disabled)	35	39
Study 1 treatment (haptic feedback enabled)	39	54
Study 2 treatment (haptic feedback enabled)	32	51

In addition to comparing students’ pre/posttest scores, students’ actual answers to the item could also be compared. For example, consider the following student’s responses to the item during the pretest and posttest from study 2, respectively:

Pretest: *The substrate approaches the active site, which is filled with water. The water is displaced and the substrate begins to enter the enzyme, which is not quite “rigid” but rather flexible, allowing the substrate to enter. Once inside, the substrate is repositioned to minimize repulsive interactions, and then it passes through a slow transition state and binds covalently to the enzyme.*

Posttest: *As the substrate approaches the active site a few attractive interactions might be created. Although this might not be enough for it to be “sucked” into the protein immediately, it will be more difficult for it to diffuse away. After a while the ligand might find more interactions where the higher the number of attractive interactions the higher the probability of binding will be. The substrate uses “trial and error” to find its optimal position inside the protein, with the highest number of attractive, and the lowest number of repulsive interactions, until it has found the best possible position and is stuck there.*

Comparing these responses was used to shed light on this particular student’s learning gain shown by the difference score. For instance, the responses indicate that this student might very well have learnt about aspects of the principle of complementary fit between protein and ligand, and associated attractive forces. In particular,

analysis of the posttest response reveals that the student has learnt about the role of attractive forces in docking, compared to the pretest response in which docking is described as a process of minimizing steric hindrance. Hence, this item was found to deliver both quantitative and qualitative information on students' learning outcomes after interacting with the model.

How can changes in understanding be identified and characterized?

Analysis of students' word usage from responses to the item is one way to investigate any changes in understanding. In particular, by considering the nature of the words that are expressed, the conceptual understanding attributed to docking can be gauged. Such analysis by Bivall Persson et al. (2007) has revealed several categories of reasoning about docking. Two reasoning categories are the chemical and force categories. Chemical reasoning is shown when students use words that describe chemical phenomena (e.g. 'acid', 'hydrophobic', 'polar'), while force reasoning consists of word usage that describes physical interactions between molecules (e.g. 'pulls', 'repels', 'attracts'). The same response from Study 2 presented in the previous section, is reproduced here, with **chemical** words in **boldface** and force words underlined:

Pretest: The **substrate** approaches the **active site**, which is filled with **water**. The **water** is displaced and the **substrate** begins to enter the **enzyme**, which is not quite "rigid" but rather flexible, allowing the **substrate** to enter. Once inside, the **substrate** is repositioned to minimize repulsive interactions, and then it passes through a slow **transition state** and binds covalently to the **enzyme**.

Posttest: As the **substrate** approaches the **active site** a few attractive interactions might be created. Although this might not be enough for it to be "sucked" into the **protein** immediately, it will be more difficult for it to diffuse away. After a while the **ligand** might find more interactions where the higher the number of attractive interactions the higher the probability of binding will be. The **substrate** uses "trial and error" to find its optimal position inside the **protein**, with the highest number of attractive, and the lowest number of repulsive interactions, until it has found the best possible position and is stuck there.

After interaction with the model, there is a two-fold increase in the frequency of the student's usage of force words, from 3% to 7% (of total word usage). Simultaneously, the frequency of chemical word usage decreases from 18% to 6%. This analysis allows for an observation of the types of, and shifts in, understanding constructed from engaging with the model.

In addition to word analysis, semi-structured interviews can be used to investigate conceptual understanding and reasoning about docking after interacting with the model. For example, consider the following student quotes obtained from interviews during study 1 and 2:

You know the chemistry... properties of different groups... different types of forces... What haptics did was to couple this together into a coherent whole.

...you never really have a picture like that of how, it [docking] happens from the outside in, maybe into some cavity where it [ligand] is influenced by forces all the time, to actually find the correct position...

...the ligand bumps around when I try to dock it. Is it really so random and dynamic? I thought it was more like a magnet, that the ligand was sucked into the binding site into one correct position...

At least three potential changes in student understanding can be revealed from analyzing interview data. For example, in the case of the first quote, there is a distinct metacognitive dimension connected to the student's use of the model. In contrast, the student who delivers the second quote clearly adds knowledge about the influence of forces to his/her already existing conception of a 'correct' binding position. Lastly, as demonstrated by the third quote, interacting with the model might also induce a cognitive conflict with the consequence of a student challenging or replacing an existing conception. Hence, interview data can provide rich insight into the impact of the model on the current status and changes in students' conceptions of the docking process.

How can real-time interaction with the model be monitored?

In parallel with the data collection instruments described above, specific tasks were also designed to obtain information about students' interaction with the system. One such exercise consisted of the following:

Write a description of how you predict the ligand to dock. Now, try to dock the ligand in the way that you have predicted. During this exercise, try and express aloud what you are thinking about and experiencing. When you have found a docking position that you are satisfied with, press the save-button.

The following verbal exchange is an excerpt taken from a think-aloud session based on the item above, delivered during a student's successful attempt to locate the correct docking site on a protein.

Interviewer: *How are you currently experiencing the potential pit [Student previously described the binding site as a 'pit' of potential energy minimum]*

Student: *Well, here [a region on protein surface] there is like a strong repulsion whereas here [makes whistle sound upon moving ligand into binding site] there is not only simply resistance, it is really as if it [...] I experience it as if it [ligand] moves inwardly in this position, it is as if you are on a shelf and whoop, there it [ligand] drops down [...]*

Interviewer: *When you say that you 'feel' your way, what do you mean by that?*

Student: *I mean that I do not base my movements on any specific theory about the exact orientations of the groups, like polar towards nonpolar or polar towards polar and so on, but rather that I try to feel my way.*

It is evident from the quote above that the student attaches his haptic experience to the intermolecular interaction between ligand and protein during interaction with the model. The student's suggestion that he "feels his way" depicts how the student exploits the force feedback to supplement his chemical reasoning with the haptic information perceived during the search process. In this way, stimulating the student to 'think aloud' offers the researcher a window into the connections between different perceptual modalities during problem solving.

In conjunction with this oral data, we also collected real-time information about students' 3D spatial interactions with the model. Specifically, the chronological sequence of students' interaction with the system was logged in the form of positions of the ligand (relative to the protein) at two-second intervals, as well as the force magnitude obtained from the potential field at each position (logged irrespective of whether students perceived haptic feedback or not). This data was used to visualize each student's movement of the ligand within a Cartesian coordinate system over time (Figure 2). Each logged position of the ligand corresponds to a sphere. Larger spheres indicate positions where the ligand experiences greater force magnitudes. Elapsed interactive time during the task is conveyed by a black-to-white shading gradient.

Figure 2 contains profiles from two students in study 1 who performed a docking task similar to the item described above. Each of the participants interacted with the model either with haptic feedback enabled (left) or disabled (right), respectively. These two patterns show marked qualitative differences. The student who docks the ligand without receiving force feedback generates a dispersed grouping of ligand positions (Figure 2, right) with no immediately observable pattern of traversal. From a purely visual point of view, the docking exploration of this student seems to be rather spatially unsystematic. In contrast, consider the docking pattern revealed by a student who received haptic feedback during the task (Figure 2, left). There appears to be a more localized and channel-like quality to the visualized pattern, indicating a more 'constrained' movement of the ligand. This is further supported from numerical data retrieved from the log files. For example, it was observed that the student who produced the profile without haptic feedback (Figure 2, right), moved the ligand a total distance two-and-a-half times greater than did the student who received force feedback (Figure 2, left).

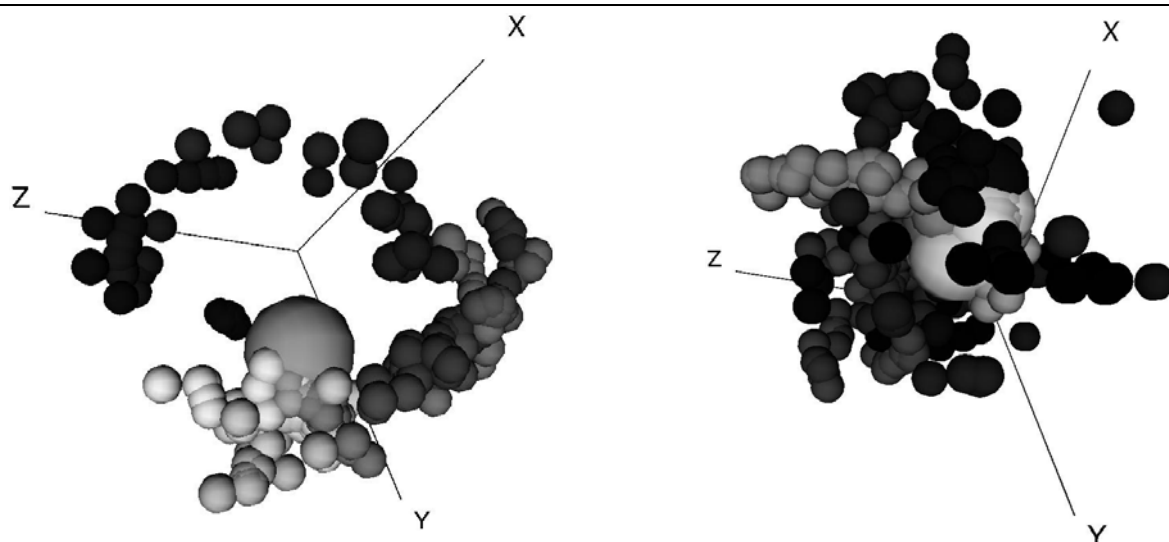


Figure 2. Examples of two students' docking profile patterns obtained with (left) and without (right) haptic feedback enabled. Shading becomes lighter as more time elapses during interaction with the model.

The methods used to visualize the patterns in Figure 2 are akin to capturing a student's docking 'journey' and externalising the resulting 'explorative sequence' adopted during a task. In conjunction with the think aloud datum presented above, the patterns in Figure 2 serve as a means of triangulation for supporting the hypothesis that force feedback induces students to 'feel out' advancement of the ligand to a feasible docking site.

Conclusions and Implications

This paper has presented methods for investigating students' learning and interaction with a haptic virtual protein-ligand docking model in response to three questions. Firstly, we measured students' learning gain through a written item in which we applied a quantitative analysis of pretest and posttest scores. Qualitative insight into the nature of individual students' learning outcomes was gained by comparing written responses before and after interaction with the model. Secondly, any changes in students' understanding were investigated by analysing the frequency of word usage in written responses. Detailed information pertaining to the construction, adjustment and replacement of students' conceptions about docking were gained through interviews. Thirdly, information about students' interactions with the model was garnered through specially designed think aloud tasks where students' were required to dock a ligand. At the same time we automatically logged 'moment-by-moment' data and visualized it to gain an appreciation of interaction patterns with the system.

Overall, in response to the need for data-gathering and analytical instruments to investigate students' learning and interaction with virtual environments in the molecular life sciences, the methods employed in our group can be used for at least three purposes, to namely:

- Obtain numerical pre/posttest scores for quantitatively measuring whether the model is associated with any learning gain.
- Characterize the nature of any learning outcomes and changes in students' biochemical knowledge by analyzing written and interview responses.
- Deliver and visualize information on students' interactive engagement with the model through think-aloud tasks and time-stamped logging data.

The methods offered in this paper have strengths and limitations. For instance, measuring learning gain informs us about the potential outcome of interaction with the system but little about the interactive process. Similarly, obtaining ‘moment-by-moment’ information yields a large volume of data that make analysis of students’ cognitive engagement with the model a challenge (e.g. Kozma, 1991). At this stage in our research, sample sizes are small since the course is specialised and a significant amount of time is required for students to familiarise themselves with the haptic system and use it to solve tasks. Therefore, it is challenging to develop and test the presented methods with large numbers of students at varying levels as well as from different contexts. Hence, we are constantly aware of the need to reflect upon the validity (and reliability) of the instruments. Nevertheless, as evidenced in this paper, our objective has been to reconcile these caveats by pursuing a triangulated approach to data collection and analysis (e.g. Gall, Borg, & Gall, 1996). Future work will be concerned with using our results (e.g. Bivall Persson et al., 2007) to fine-tune the presented methods to explore the role of biomolecular haptic models in embodied learning (e.g. Dede, Salzman, Loftin, & Ash, 2000).

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MODEL OF COGNITIVE ARCHITECTURE OF COMMON AND SCIENTIFIC CONCEPTS

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Educational Publisher Didaktis

Abstract

The cognitive architecture of concept is a specific structure consisting of the concept core, concept periphery, the semantic frame as the meaning and the sense of the concept, and the relations among all components of this structure. The core of a concept is composed of three mutually linked elements: a symbol, a representative semantic image – RSI (prototype or core of a conceptual category), and an intrinsic structure. The periphery of a concept is composed of the set of meaning and sense links to the all concepts which can be meaningfully connected with the given concept core in symbolic expression, speech or thought. The model of the cognitive architecture and four developmental levels of scientific and common concepts are presented: primitive, empirical, exact, and formal. The model is built upon Vygotsky's concept theory, Fillmore's semantic frame, semantic triangle, on widespread ideas of the structuring of conceptual systems, and the Hestenes' Modelling Theory. The method of semantic mapping of concepts flowing from the model is designed.

Introduction – Theoretical Problem

Several important features characterize scientific thinking which leads to new discoveries: chunking, the seeking of relations, the building of structures, imagination, and visualization. Mankind survives because “we have evolved the ability to ‘cut up’ that world into chunks about which we can think and hence give meaning to” (Gilbert et al, 2008). The process of chunking and then seeking the relationships between these ‘chunks’ as a part of cognition (especially scientific cognition) is called modeling and the products of these mental actions are called (scientific) models. Scientific knowledge is characterized by a system of scientific concepts, terms, facts, laws, principles and the connections between them which comprise theories and their applications and interpretations in reality, and cognitive, modeling, application, and interpretation methods and procedures that the given science makes use of. Scientific conceptual knowledge systems are organized in scientific models described by words, symbols, or figures which comprise patterns. How to teach and learn the scientific concepts, models, and knowledge effectively is an important problem in the science education research (Hestenes, 2009, Tarábek, 2009). According to Carl Wieman (2007), recipient of the Nobel Prize in Physics in 2001, “novices see the content of physics instruction as isolated pieces of information – handed down by an authority and disconnected from the world around them – and that they can only learn by memorization. Experts – i.e., physicists – see physics as a coherent structure of concepts that describe nature and that have been established by experiment... The traditional lectures are simply not successful in helping most students achieve mastery of fundamental concepts.” A part of this problem is the detail structure of (mental) common and scientific concepts used as human tools for cognition in science, mathematics, and in everyday life, which is also a long-term problem in cognitive psychology and science.

Theoretical Method – Modeling

The author's studies were focused on the understanding of mental representations of misconceptions and knowledge in the minds of pupils and students and have resulted in the creation of the **triangular model of concept structure**, which describes a structure of common and scientific concepts and their semantic frames as basic components of conceptual knowledge systems created by humans (Tarábek, 2007, 2008). It is also an attempt to model the structural properties of components of mental conceptual knowledge systems of intelligent agents (human or artificial). In this meaning, the term 'cognitive architecture' is used in cognitive science. The term 'architecture' implies an approach that attempts to model not only behavior, but also the structural properties of the modeled system. These need not be physical properties: they can be properties of virtual machines implemented in physical machines, e.g. brains or computers. The term 'cognitive architecture' used in cognitive science also means "an embodiment of a scientific hypothesis about those aspects of human cognition that are relatively constant over time and relatively independent of task" (Ritter, Young, 2001, Sears, Jacko, 2008).

In the light of cognitive science, the **triangular model of concept structure** describes the cognitive architecture of a concept and its semantic frame. Then the triangular model of the concept structure may be also called the model of a cognitive architecture of common and scientific concepts. **The model of a cognitive architecture of concept** is built upon the concept theory of Vygotsky (1986), the conception of the 'semantic frame' (Fillmore, 1976, 1982), the semantic/semiotic triangle, on widespread ideas of the structuring of conceptual systems (Guilford, 1967, 1988, Bergeron, 1999, Merrill, 2002, Novak, 1993, 1998, Sternberg, 1999, Thagard, 1996), and the Modeling Theory of Hestenes (1987, 2006, 2007). This model captures the structure of concept and its semantic frame, where the term concept is taken in the same sense that it is used in cognitive psychology (Sternberg, 1999). Besides the description of concept formation (Tuomi, 1998) through the Vygotian phases (Tarábek, 2007), the model distinguishes four phases in the development of common/scientific concepts: primitive, empirical, exact, and formal. The levels of the common concepts are the primitive and empirical. The levels of the scientific concepts are the exact and formal. The model also distinguishes the concept's meaning and sense as two disjunctive sets following Frege's idea of reference/meaning and sense (Frege, 1892). The idea of different kinds of meaning is also used in Double R Grammar concerning language comprehension (Ball, 2004), where the relational and referential meanings are distinguished – the relational meaning corresponds to the sense and the referential meaning to the meaning in the triangular model of concept. The basic components of the model are: the core of a concept, the periphery of a concept, the meaning M and the sense S of a concept, their mutual connections and also the hierarchical layers of the meaning.

Conceptual Knowledge Systems

The Modeling Theory of Hestenes (1987, 2006, and 2007) distinguishes two models of the physical world: conceptual and mental. The conceptual model is a representation of structure in a mental model (Hestenes, 2007) or in a material system (real or imaginary) and the mental model represents states of the world as conceived, not perceived (Hestenes, 2006). The conceptual model may be a scientific or model represented by a common language system. The conceptual models and the mental models as referents of conceptual models are conceptual knowledge systems (CKS) where two types of the CKS are distinguished: internal/mental CKS and external CKS. The **conceptual knowledge system (CKS)** is a pair $[M, R]$, where M is the set of all elements of CKS – concepts, knowledge, and their components, and R the set of all relations between the elements of CKS.

The internal conceptual knowledge system (ICKS) is a result of the individual cognitive process of a human. It is a system of concepts and knowledge which an individual acquires and forms through the process of education, learning, observation, and empirical experience, as well as in the process of scientific cognition through goal-oriented experimentation and through his/her own thinking. The internal conceptual knowledge system is comprised of elements and the relations between them. The basic elements of the ICKS are concepts at various

levels of abstraction and formation. The concepts are also systems and involve ‘mental words’¹², mathematical, physical, and other ‘mental signs’¹³, mental semantic images expressing a class of denotata (objects, phenomena, events in reality, and entities to which the given concept refers), features of denotata, and other mental images at various levels of abstraction. The ICKS also contains experiences and perceptions stored in the memory if they are parts of concepts or knowledge. Relationships between the elements of the ICKS are of various types – as connections between components of concepts and among the concepts, and as declarative knowledge such as specific cognitive connections between the concepts. The parts of the ICKS are also procedural knowledge as seen in intrinsic rules of several types of human reasoning: abductive, deductive, inductive, analogical, metaphorical, analytical, and synthetic (Hestenes, 2006), and specific procedural knowledge¹⁴. The **concepts** as elements of the ICKS are mental representations of categories (Medin, Heit, 1999, Byrne, 2004) where “the category is a set of objects that share some features in common, somehow distinct from objects in other categories. In the classical Aristotelian view, concepts are proper sets, defined by list of features that are both singly necessary and jointly sufficient to identify an object as an instance of a category (Leary, MacDonals, Tangney, 2005)”. To distinguish the concepts as elements of the ICKS from the concepts as elements of the external conceptual knowledge systems and from the term ‘concept’ in Hestenes (2007), we use for them the term **internal concepts** or the term **mental concepts** (SEP, 2009). The world of the human mind also involves mental images and constructions – more or less clear, which are not connected with mental words and are not parts of mental concepts. These mental constructions are not expressed by words and if they are represented by specific mental pictures with critical attributes of the denotata (the RSI, see the next section) we can call them **non-verbal concepts**. We can also call them *ideas* or *intuitions* which can be “elevated to concepts by creating symbols to represent them” (Hestenes, 2006). Much of the mathematical and physical thinking of physicists at the conscious level is imagistic without words. “The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. . . . The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be voluntarily reproduced and combined. . . . The above-mentioned elements are, in my case, visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary state. . . from a letter by Einstein, in the paper of Hestenes (2007).”

The external conceptual knowledge system (ECKS) is the result of the social cognitive process, i.e. the cognitive processes of human society as a system of cognitive agents, while it is necessary to distinguish which system is being discussed. **The scientific conceptual knowledge system (SCKS)** is the result of the cognitive process of a scientific community in a given science. It consists of the scientific concepts, terms, facts, laws, principles, theories, their applications and interpretations, and cognitive, modeling, application, and interpretation methods and procedures that the given science makes use of. The scientific external conceptual knowledge system also includes the scientific representation of reality (from the point of view of the given science) – the system of general images of the reality consistently connected with the scientific knowledge and formulated usually in the natural language with scientific terms. The scientific ECKS also involves concepts of the natural language that scientists/experts use when they present scientific results to people who are not experts in the given science. The representations of scientific conceptual models of Hestenes (2007) – “in concrete inscriptions of words, symbols, or

¹² Mental words are units of the mental language (Wittgenstein, 2008) or the Language of Thought (Fodor, 1975) and also parts of mental concepts whereby human beings express mentally the things, objects, processes, and entities which they are thinking. The Language of Thought Hypothesis (LOTH – Fodor) postulates that thought and thinking take place in a mental language. The Language of Thought consists of a system of representations that is physically realized in the brains of thinkers.

¹³ Mental signs are derived from conventional signs, symbols, and icons of common or scientific language and have the same semantic content.

¹⁴ Specific procedural knowledge means specific rules of mathematical and scientific thinking used to solve concrete scientific tasks and problems.

figures” – are also parts of the scientific ECKS. The **concepts** as components of the **external conceptual knowledge system** are also systems and involve words, mathematical, physical, chemical, and other signs (symbols, icons, tokens, diagrams, etc.), semantic images expressing denotata class (objects, events, phenomena in reality, and entities to which the given concept refers), features of denotata, and other semantic images at various levels of abstraction. To distinguish the concepts as elements of the ECKS from the concepts as elements of the ICKS, we use also the term **external concepts**¹⁵ for them.

Result – Model of Cognitive Architecture of Concept

The **model of the cognitive architecture of concept** describes a specific structure of common or scientific concepts and their semantic frames as components of the conceptual knowledge systems, which may be external or internal – mental. The basic components of the model are: the **core** of a concept, the **periphery** of a concept, the **meaning** M and **sense** S of a concept, their mutual connections and also the **hierarchical layers** of the meaning (see Fig. 3). The **semantic frame** of the concept consists of the **meaning**, and the **sense**. The model distinguishes between the concept’s meaning and sense as two disjunctive sets following Frege’s idea of sense and reference/meaning (Frege, 1892). The model of the cognitive architecture of concept is represented by a triangular form in Fig. 1; therefore we can call it the **triangular model (TM)**. The **meaning** of a concept in the TM is a set of all subordinated concepts and images and also the relations between them and the core. The concepts and images of meaning represent objects, events, processes, and phenomena of the real world, and they also represent entities as conceptual constructs modeling things of the real world. The **sense** of a concept in the TM is a set of concepts assigned to the concept core which can be in symbolic expression, speech or thought meaningfully connected with the given concept core (except for subordinated concepts) and sense links from the core to the assigned concepts. The TM models both kinds of concepts: external as well as mental. Fig. 2 shows the relation of reference between mental and internal concepts and also the relations of representations to the real world. The internal (mental) concepts are private constructions in the mind of an individual which are used in his/her speech and thought as activating elements – they activate words of speech or ‘words’ of thought as internal speech. The internal/mental concepts (MC) can be elevated to external concepts as models of MC by encoding elements and structures of mental concepts in symbols – words, signs, icons, semantic images etc. (see Fig. 2 – link of construction). In reverse, these symbols activate the individual’s mental concepts and corresponding mental concepts in the minds of other individuals. Thus the external concepts are shared conceptual models of humans.

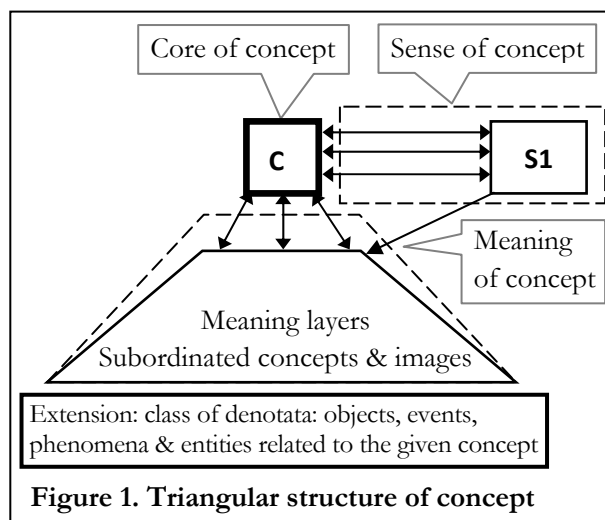


Figure 1. Triangular structure of concept

The **CORE** of an external concept is composed of three mutually linked components: a **symbol** (e.g. a word or assembly of symbols: a word and a sign/icon), a **representative semantic image** – RSI, and an **intrinsic structure** of the concept – the internal components of the concept and the relations among them.

¹⁵ In cognitive psychology, cognitive science and science education research, the term ‘concept’ is used in both meanings: the ‘mental’ concept as an element of mental models of reality in the human mind, and also the ‘external’ concept as an element of conceptual models of reality – scientific or expressed by common language.

The **core** of a mental concept is composed of three mutually linked components: a **mental word** and/or mental sign/icon, a **mental RSI**, and a **mental intrinsic structure** of a concept – the internal components of the concept and the relations among them. The **mental RSI** is the dominant structured image that emerges in the mind after one says a given word and may appear in the mind during a thought operation with the mental word or symbol. The mental RSI may be a mental prototype (Rosch, 1973, 1978). The **external RSI** is a part of an external concept. The external RSI as an **external prototype** contains a list of characteristic/critical features that the object in extension of the related concept tends to possess. The list of features is applied by judging the similarity between the RSI and the mental representation produced by an object as it is experienced. Thus the RSI corresponds to the **prototype** of the natural category (Rosch, 1978) or the perceptual category (Nolan, 1994) and the mental RSI is an image form of the prototype. The external RSI as a **core of a conceptual category** (Armstrong et al, 1983, Nolan, 1994, Sternberk, 1999) contains a list of characterizing properties – **attributes** of objects in the extension of the related concept. The attributes are used in definitions together with the superordinate concept (see ‘attributive sense links’ in the next page).

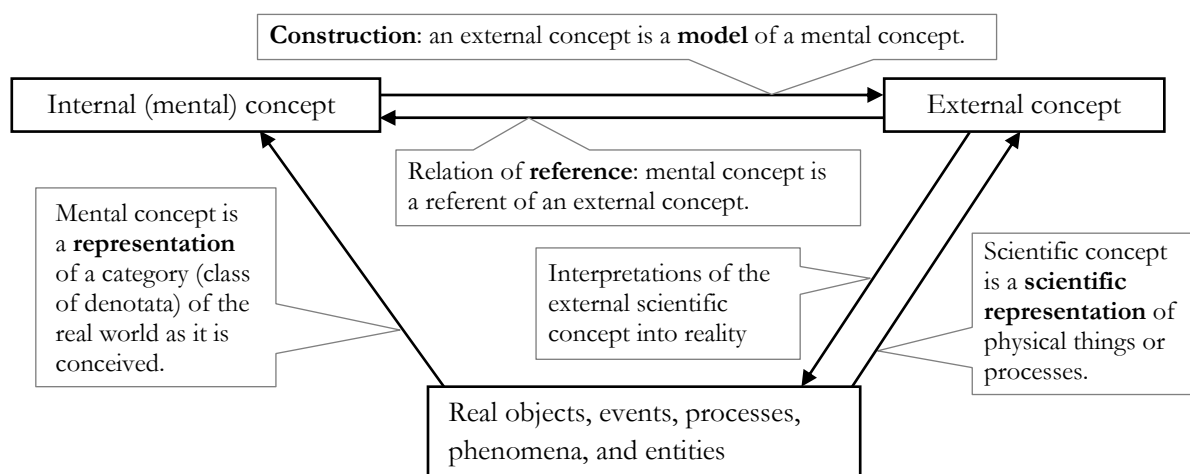


Figure 2. Mental and external concepts: relations of reference, modeling, and interpretation.

The **intrinsic structure** means a system of relations among attributes (or among features of a prototype). For example, the attributes of a triangle are three vertices and three sides. The intrinsic structure is a system of relations among the constituent vertices and sides of the triangle. The attributes of an iron ball are its mass, volume, and spherical shape (given by its radius and surface). The intrinsic structure is a system of relations between the volume and the mass, between the radius and the volume, and between the radius and the surface. Highly abstract concepts probably possess no intrinsic structure. For example, the attributes of a solid body are its mass, constant volume and constant shape. The relations among these attributes belong to concrete solid bodies only (e.g. an iron ball, wooden cube, or glass ball). We cannot speak about the relations among the properties of an abstract solid body. The attributes of a mass point are its mass and zero volume. There is also no intrinsic structure between the mass and the ‘volume’ of the mass point. The **mental intrinsic structure** is a mental model of the external intrinsic structure.

The **PERIPHERY** of a mental/external concept is composed of the set of **meaning** and **sense links** from the concept’s core to the all concepts of the meaning and sense which can be meaningfully connected with the given concept’s core in symbolic expression, speech or thought in a frame of the given mental/external conceptual knowledge system. The relation to the superordinate concept belongs also to the periphery.

The **MEANING** of a concept is composed of the set of all cores of subordinate concepts and sets of images referring to the given core and also of the set of **meaning links** from the core to the subordinate concepts and images (see Fig. 3). In the meaning of the concept, we can differentiate hierarchical **meaning layers**. The **meaning layer M1** is the set of the most abstract concepts which are subordinated to the given concept core and divide the whole class of denotata into disjoint subclasses. For instance, the class M1 of subordinate concepts of the

concept 'force' is composed of the concepts: 'gravitational force', 'electromagnetic force', 'nuclear force', and 'weak interaction'. However, it is necessary to emphasize that other classes of such concepts may exist in the scientific system of physics. Forces are divided, for instance, into real and fictitious classes in classical mechanics. The real forces are divided into distant and contact. **The meaning layer M2** is a set of concrete concepts and semantic images which may be subordinate to the abstract concepts of M1 or to core C. For example, the concepts of contact forces (pushing and pulling forces, friction, and air resistance) and concepts of distant forces (electrical, magnetic, and gravitational) comprise set M2 of the concept 'force'. The **meaning layer M3** is a set of concrete semantic images of denotata in a concrete situation which refer to the core C or to the elements of M2 and M1. The mental images can be perceptions of concrete objects, events, phenomena, etc. stored in the memory or mental constructions of them. The external semantic images can be diagrams or pictured constructions of concrete objects, events, phenomena, etc. of reality. The **extension E** of the given concept is the class of **denotata** – objects, phenomena, events in reality and entities to which the word or symbol of the given concept points. The extension is not a part of the meaning. **Meaning links** are firstly the links between the concept core and subordinate concepts or images, and, secondly, all other links between the elements of the meaning layers.

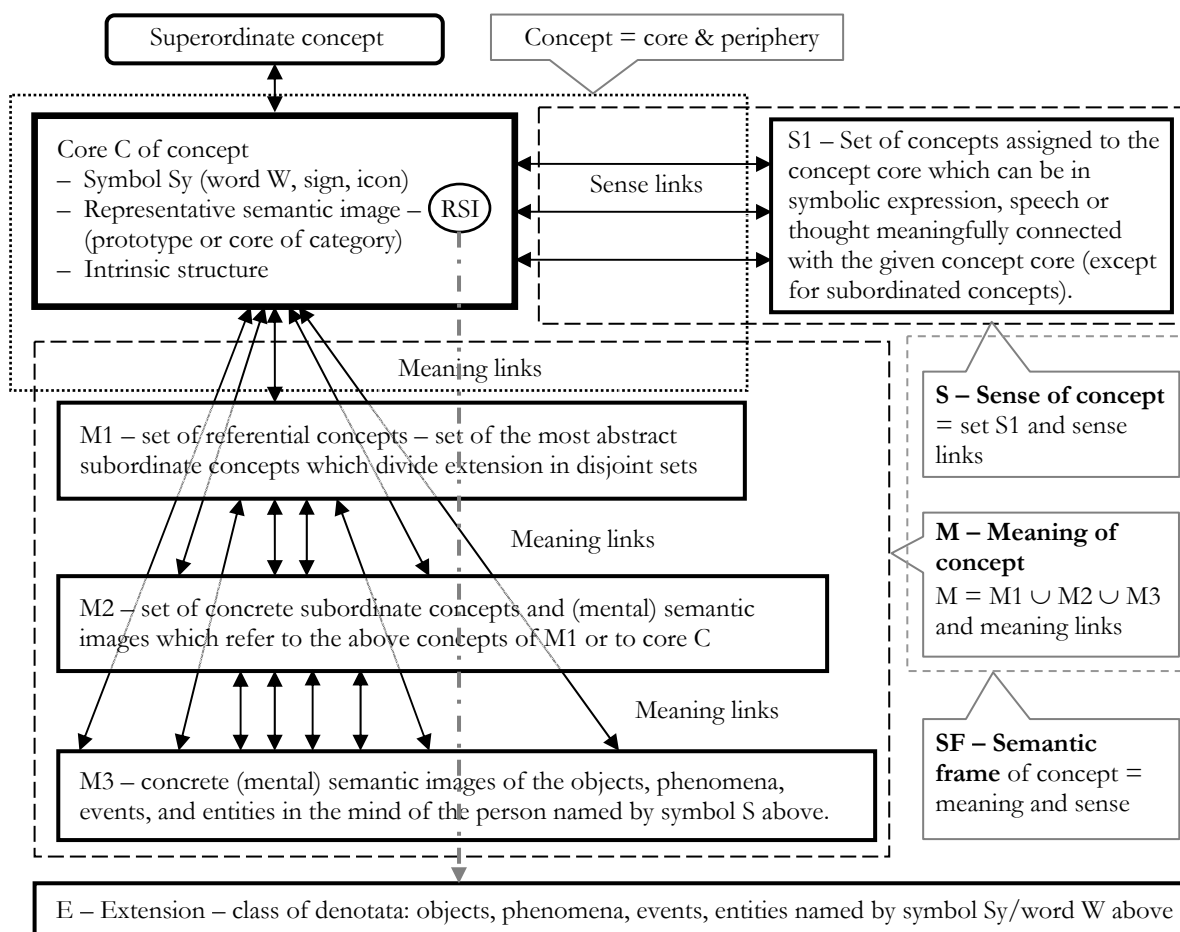


Figure 3. Triangular model of cognitive architecture of common and scientific concepts

The rectangular boxes represent the components of the cognitive architecture (core C, S1, M1, M2, M3), the dashed boxes represent subsystems (meaning M and sense S – semantic frame SF), the dotted box represents a complete concept (core and periphery), and the arrows represent links between the components of the cognitive architecture of concept. The dotted-dashed (grey) link expresses the assigning of observed objects, events, and entities to the given concept of force by the RSI.

The SENSE of concept consists of the set S_1 of assigned concepts which can be meaningfully connected with the given concept core (except for subordinated concepts) in symbolic expression, speech or thought and **sense links** from the core to the assigned concepts (see Fig. 3). We can divide **sense links** into qualitative, attributive, cognitive, operational, and contextual types.

Qualitative sense links are the links to concepts which express **potential qualities**. **Potential qualities** are properties characterizing denotata of subordinate concepts belonging to the meaning. The connection of potential qualities to a given concept results in its division into subordinate concepts. For example, the potential qualities of a tree are expressed as 'broad and flat leaves' or 'needles'. Thus the class of trees is divided into two disjoint subclasses: deciduous trees and conifers. The potential qualities of a human are male and female. Thus the class of humans is divided into two disjoint subclasses: men and women. Potential qualities connected to the concept 'force' are 'gravitational', 'electromagnetic', 'nuclear' and the quality expressed by the term 'weak interactions'. Thus the general concept of force is differentiated into referential concepts: 'gravitational force', 'electromagnetic force', 'nuclear force', and 'weak interaction'.

Attributive sense links are the links to concepts which express **attributes** of a given concept. **Attributes** of a given concept are the relevant properties characterizing the denotata class (objects, phenomena, events, and entities denoted by the name of the concept)¹⁶. According to these properties, we are able to categorize an observed object, phenomenon, event or entity into a denotata class (an extension of the given concept). For instance, the concept 'body' has its mass as an attribute. The concept 'force' has an attribute the fact that the force causes acceleration or deceleration of a body's motion or a curving of its trajectory. The concept 'husband' has two attributes: married and adult. Thus a husband is a married and adult man. (The 'man' is a superordinate concept).

The **attributes** are used in definition together with superordinate concept. For instance, in the definition 'Body is a mass object', 'object' is a superordinate concept while 'mass' is an attribute. In the definitions 'Solid body is a mass object with constant volume and shape' or 'Liquid is a mass object with constant volume and variable shape', 'mass object' is a superordinate concept and 'constant volume' and 'constant/variable shape' are attributes. In classical mechanics, 'a force is the cause of acceleration or deformation of the body' (where the acceleration means acceleration, deceleration or curving of the trajectory). The cause is the superordinate concept. The acceleration and deformation are the attributes. In the definition: "In mechanics, a force is an interaction that causes acceleration or deformation of a body" (Glenn, 2008), 'interaction' is a superordinate concept whereas 'acceleration' is an attribute. In modern theoretical physics, 'a force is a mutual interaction of physical bodies or bodies and fields'. The term 'force' is replaced by the term 'interaction', the formal concept 'interaction' has no superordinate concept (it is a primary term) and no attribute. The specific interaction is expressed by a relevant mathematical formula.

Cognitive sense links are links between the core of the given concept and concepts that are related to physical and natural law (rule, principle) together with this concept. For example, if we consider Newton's second law in the form $F = m \cdot a$, the cognitive links of the force F are given by this formula, e.g. ' $a \propto F$ ', ' $F \propto a$ ', ' $a \uparrow \uparrow F$ ', and from the light of the Newtonian conception, the link ' $F \Rightarrow a$ ' (a force causes the acceleration) also belongs to the above ones. If we consider mental conceptual knowledge systems, students have a mental cognitive link ' $F \Rightarrow a$ ' from the concept 'force' to the concept 'acceleration' if they understand that a force causes the acceleration of

¹⁶ Some concepts have no typical attributes. For example, we cannot sufficiently specify the properties of a bird. We can say that wings, feathers and beaks are characteristic properties of a bird. But what about penguins or chicks? Do penguins have feathers? Yes, they do, but they are not typical feathers. Do chicks have feathers? They only have fluff. These concepts belong to natural categories (Rosch, 1973) where we cannot speak about typical attributes. We can speak about **characteristic** or **critical features/properties** when the attributive links connect the given concept with the concepts expressing characteristic/critical features/properties.

a body's motion or the curving of its trajectory. Another cognitive link is ' $a \propto F$ ', i.e. the acceleration is directly proportional to net force (when mass is constant), or ' $\mathbf{a} \uparrow \uparrow \mathbf{F}$ ', i.e. the acceleration has the same direction as the force. Another example: if we consider the formula $O = 2\pi R$ for the calculation of the circumference of a circle, the cognitive link between the circumference and the radius means understanding that the circumference is 2π -times greater than the radius of a circle.

Operational sense links are the links between the core of the given concept and concepts that belong to physical or mathematical definitions using variables together with the given concept. These links are also expressed by operational definitions, or correspondence rules for assigning measured values to states of the physical system (Hestenes, 2006) which are realized by mathematical formulas or thought operations. Operational links exist in the mind of a student if he/she knows how to 'read' the physical definitions. For instance, if a student knows how to 'read' the definition ' $s = v \cdot t$ ' (path equals product of steady speed and time), in the structure of his/her concept of 'path' there are the links ' $s \propto v$ ' (path of steady motion is directly proportional to the speed of motion) and ' $s \propto t$ ' (path of steady motion is directly proportional to the length of time interval). If a student knows how to read the definition $\mathbf{a} = d\mathbf{v}/dt$ (acceleration is the derivative of speed with respect to time), he/she knows and understands that 'acceleration is directly proportional to the differential change in speed' and 'inversely proportional to the differential change in time'. Operational links mean also connections between physical quantities and the units which are used to measure them.

Contextual sense links are the links between the core of a given concept and all other concepts that may be meaningfully connected with the given concept in statements, propositions, sentences, etc. This term does not designate qualitative, attributive, cognitive and operational links. For instance, the concept 'force' can be meaningfully connected in sentences with the concepts 'motion', 'action', 'field', 'space', 'time', etc. Contextual links between concepts are realized in arranging words into meaningful statements. Clearly, the sentence: "The car has green leaves" is meaningless, because there is no contextual link between the concepts 'car' and 'green leaves'. Contextual links enable us to create predicates – verbal statements concerning attributes, laws, definition assignments and also statements concerning meaningful links from a given concept both downwards and upwards.

The **triangular model of cognitive architecture** of concepts distinguishes four **LEVELS IN DEVELOPMENT OF CONCEPTS: primitive, empirical, exact, and formal** (Tarábek, 2009, Fig. 2, where 'symbolical' means the exact level). The empirical concepts at the empirical level are concepts of common language (or CS concepts of Hestenes, 2006), the exact concepts at the exact level are components of scientific conceptual knowledge systems, and formal concepts at the formal level are components of mathematical theories or formal theories in physics. The empirical and exact developmental levels were also indicated by the study of students' concepts in the process of education (Tarábek, 2008). The empirical level (called the Aristotelian level) of the concept 'force' was identified by the students' formulation 'force is needed to keep a body in motion', and similar expressions. The Aristotelian law 'force causes (violent) motion' came directly from an observation as a generalization of empirical experience and this (or similar) conception of force in students' minds is called the Aristotelian preconception. The symbolical level (called the Newtonian level) was identified by the students' formulation 'force causes a change of motion of the body – acceleration, deceleration or the curving of its trajectory' and similar expressions.

The semantic analysis searches for components of a structure of a given concept and its semantic frame and **SEMANTIC MAPPING** arranges them into the systemic pattern following the structure of the triangular model. We have to take into consideration that the triangular model is three-dimensional (see Fig. 4). Therefore the structure of the semantic map depends on the level of development of a given concept and its semantic frame. Secondly, the semantic map has two dimensions – vertical (the direction to the meaning and superordinate concept) and horizontal (the direction to the sense). The semantic maps are presented e.g. in Tarábek (2009, Fig. 3 and 4).

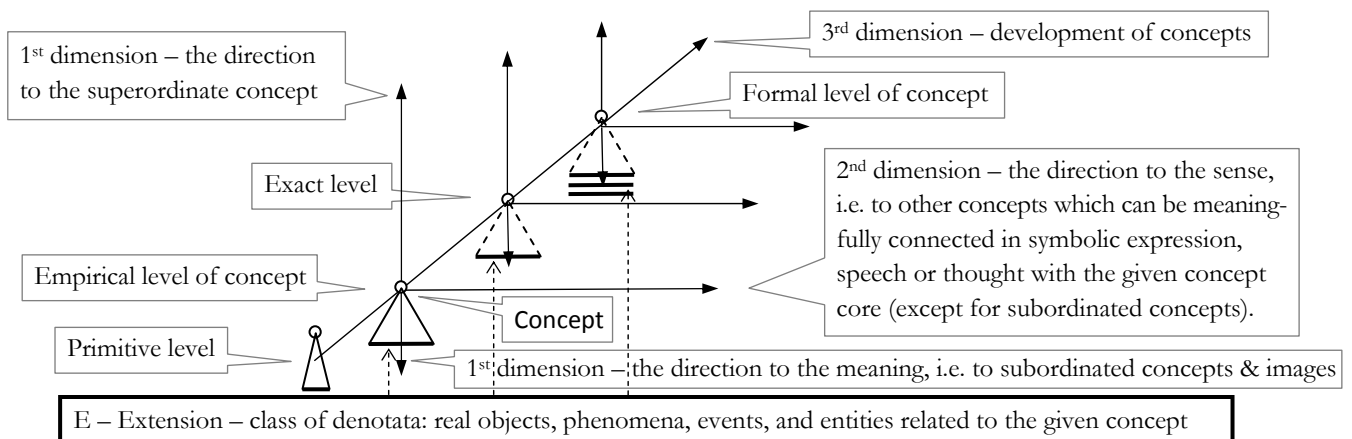


Figure 4. Three dimensions of the triangular model of cognitive architecture of concepts

Conclusions and Implications

The **Model of the Cognitive Architecture of common and scientific Concepts (MCAC)** is a theoretical construct based on the knowledge and terminology of cognitive psychology, cognitive sciences and educational research that shows a structure of external common and scientific concepts, their semantic frames and a possible structure of internal (mental) concepts and their semantic frames in a human mind. It does not yet cover all terms and phenomena described in cognitive science and psychology concerning the concepts. But the method of semantic analysis flowing from the MCAC allows the analysis of a structure of concepts and their semantic frames as components of external conceptual knowledge systems and to study a structure of their mental models in learners' minds. The results of the semantic analysis by the MCAC allow us to construct semantic maps of concepts.

The model was also used to solve problems concerning the mental structure of misconceptions and scientifically correct knowledge. Differentiation between the empirical (pre-scientific) and exact (scientific) levels of concept development has shown that many misconceptions in mechanics are developmental states of human cognition at the empirical level (Tarábek, 2008), i.e. preconceptions or "CS misconceptions" (CS – common sense), which "were clearly articulated by great intellectuals – Aristotle, Buridan, Galileo, and even Newton himself before writing *Principia*" (Hestenes, 2006). These preconceptions are very resistant to instruction and also have a significant influence in the formation of new knowledge. If students learn Newton's laws of motion, the CS-concepts remain "wrapped up in Newtonian words" (Hestenes, 2006) in their memory and the percentage of students thinking at the empirical level of the concept 'force' (so-called Aristotelian) tends to increase with age together with the Newtonian level (Tarábek, 2009).

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THE DISCIPLINE - CULTURE MODEL AND CONCEPTUAL ANALYSIS IN SCIENCE EDUCATION: THE CASE OF TEACHING QUANTUM FIELD THEORY

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Abstract

The contribution concerns the results of a study exploiting the educational and cultural potential of a topic from contemporary physics developed within the PhD thesis of the first author. The study concerns the application of the Discipline-Culture Model (DCM), suggested by Tseitlin and Galili (2005) for demonstrating the cultural relevance of the equation considered emblematic in contemporary physics: the Klein Gordon Equation (KGE). The study is framed within the general problem of reconstructing, from an educational point of view, of the main conceptual steps that took place in modelling object and interaction from classical to contemporary physics. The study, carried out in a collaboration between the physics education researchers of Bologna and Jerusalem, has been developed in three steps: i) analysis of university textbooks; ii) analysis of data collected by means of interviews and questionnaire to experts; iii) re-analysis of KGE in the light of the DCM. The main results concern: (a) the revealed problematic educational issues related to the lack of a cultural perspective in teaching KGE and, in general, in Quantum Field Theory (QFT) teaching; and (b) the effectiveness of the DCM as a perspective for reanalysing the content knowledge about KGE and exploiting its cultural and educational value.

Introduction

This contribution aims to present the results of a study focused on exploiting the educational and cultural potential of an analysis of a topic from contemporary physics developed within the PhD thesis of the first author. The study regards the application of the Discipline-Cultural Model (Tseitlin, Galili, 2005, 2008) for reconstructing the cultural meaning of a central topic in Quantum Field Theory: the Klein Gordon equation.

The general perspective of the whole work addresses the reconstruction from an educational point of views of the main conceptual steps in the transition from classical to contemporary physics; this perspective matches the agenda of re-thinking physics curriculum *at university level* as well as (in the future) *at secondary schools* in order to include certain conceptual account of modern physics.

The questions orienting the whole work are the following ones:

How the concept of *object* changes when moving from classical to contemporary physics, in particular to the Quantum Field Theory?

How the concepts of *field* and *interaction* are shaped and conceptualized within the QFT? What makes quantum field and interaction similar and what makes them different with respect to the classical ones?

The stated goals brought us to deal with meta-issues of methodology rising in exploration of “extreme territories” of physics content where physics education research (PER) faces the problem of establishing its own identity (Tseitlin, Galili 2005, 2008) with respect to physics and the philosophy of physics (Bertozzi et al., 2008).

After a brief description of the initial results obtained in our analysis of the structure and contents of the QFT, we will address the study, research questions and hypothesis, which emerged within the collaboration between science education researchers of the University of Bologna and the Hebrew University of Jerusalem.

Rationale

The research questions have been investigated along two main lines of analysis:

- The first line regards the analysis of the *structures that remain essentially invariant* in the transition from classical to modern physics: Bertozzi et al. (2008) described the so called “skeleton of continuum” – the essential structure that highlights the common between vibrating string and quantized field.
- The second line analyzes the *models of objects and interaction which change their status* in the transition from classical to modern physics: Bertozzi (2008a) focuses on how the object – *field* – changes in the transition from classical to quantum field and searches for the points of discontinuity.

The study here considered has been developed in collaboration with Galili at the Hebrew University of Jerusalem. It employs the Discipline-Culture approach and applies it to the content analysis of the area of the contemporary physics – the QFT, focussing on one of its topics: the Klein Gordon equation.

The Discipline-Culture Model: a new educational perspective

The Discipline-Culture (DC) model constitutes a new educational perspective (Tseitlin, Galili, 2005, 2008). In particular, this model defines the meaning of *culture* with regard to the elements of physical knowledge and elaborates the relationship between fundamental physical theories. Moreover, the DC perspective can guide the critical analysis of physical contents surpassing a mere focus on solving standard problems in educational context and encouraging learners' construction of the meaningful conceptual knowledge which would highlight the culturally upgraded disciplinary knowledge.

Very briefly the Discipline-Culture Model considers Physics as a dialogue between several discipline-cultures (Newtonian Mechanics, Classical Electrodynamics, Quantum Mechanics...) each of them characterized by:

I nucleus – which defines the identity of the discipline-culture and includes its fundamental principles, paradigm and claims of meta-disciplinary nature;

II body knowledge – which incorporates all normal disciplinary knowledge. This is established knowledge, each item of which is based on the principles contained in the nucleus;

III periphery – which contains the knowledge that conflicts with the principles of the particular nucleus. This knowledge presents a challenge for the fundamental claims of the nucleus and possibly a mechanism for its change and reconstruction.

Cultural knowledge of physics presumes elements of these three types, and it is in contrast to a *disciplinary knowledge* which ignores the periphery. The adepts of disciplinary knowledge consider periphery elements as disturbing the particular subject matter and causing confusion of the novice learner of physics.

The Klein Gordon equation as a paradigmatic case

In the contemporary physics, the Klein Gordon equation presents one of the fundamental equations of the QFT. In particular, it accounts for spinless, massive and relativistic particles. Moreover, its simple form constitutes the paradigmatic case for other more complicated equations (such as Dirac equation) whose field quantization leads to the description of other kind of particles (such as electron) according to the Standard Model.

In the course of this study the Klein Gordon equation appeared to be a fruitful example of a subject to be analyzed from the cultural point of view. There are several other reasons for that:

- its history involves the main difficulties physicist faced on the way to matching Quantum Mechanics with the theory of Special Relativity;
- it allows to pick up the fundamental and peculiar conceptual features of modelling objects and interaction within the QFT with a minimal formalism;
- its interpretation in the *non quantum version* is still problematic *and* shows some points deserving deeper investigation (Bertozzi, 2009).

Methods

The study has been carried out along the following steps:

1. Analysis of the equation in physics from the Discipline-Culture perspective;
2. Analysis of the equation in physics teaching from the Discipline-Culture perspective.
3. Re-analysis, on the basis of the results obtained, of the content knowledge about the KGE from the cultural perspective highlighting its educational potential.

In more detail:

1. The analysis of physics contents revealed the *status* of the KGE equation as a conceptual construct belonging to several *discipline-cultures*. However, the few known applications of the KGE, being related to very specific domains (such as cold plasma physics), are rarely mentioned in general physics courses. Therefore, the first problem of the educational realm within the cultural perspective was to build a general framework of coherent presentation of the KGE applications in various contexts, which will allow deeper exploration of the subject. To be successfully applied, the DC model requires a genuine understanding of different cases in which the same content knowledge is applied. One needs to locate the knowledge and to highlight conceptual overlaps of its different domains. Furthermore, the problematic historical path of the equation posed specific problems to be resolved by physicists at the level of physics foundations in order to reach clarity of the topic. The study carried out at this level is an emblematic case for illustrating how and why physics education has to interfere with the research in theoretical physics and the foundations of physics.

2. The analysis of the equation in physics teaching has been carried out through analysis of the textbooks, interviews and questionnaire administrated to physics experts.

Textbooks: we inspected a representative set of 16 textbooks used in advanced university courses of modern and classical physics (Relativistic Quantum Mechanics and Quantum Field Theory, Classical and Quantum Electrodynamics, Classical Mechanics) published in English and Italian (see Table 1). The analysis has been carried out in order to search for:

- the area/areas of physics where the KGE is currently presented to students;
- the importance usually ascribed to the KGE in presenting modern physics (for example, how it is currently introduced, at what level of details).

Table 1. List of textbooks

1) Bjorken J.D. & Drell S.D, 1964, <i>Relativistic Quantum Mechanics</i> , New York St.Louis San Francisco Toronto London Sydney, McGraw–Hill Book Company	9) S.J. Chang, <i>Introduction to Quantum Field Theory</i> , 1990 Singapore, World Scientific publishing Co.Pte.Ltd
2) Schweber S., 1961, <i>An Introduction to Relativistic Quantum Field Theory</i> , Evaston, Illinois Elhsford, New York, Row, Peterson and Company	10) Huang K., 1998, <i>Quantum Field Theory</i> , New York, Wiley-Interscience
3) Bethe H.A., de Hoffmann F., & Schweber S., 1955, <i>Mesons and fields</i> , Vol. I, Evaston, Illinois White Plains, New York, Row, Peterson and Company	11) Schweber S.S., 1994, <i>QED and the Men Who Made It: Dyson, Feynman, Schwinger, and Tomonaga</i> , Princeton University Press.
4) Penrose R., 2004, <i>The road to reality</i> , UK, Knopf	12) Weinberg S., 1995, <i>The Quantum Theory of Fields</i> , Vol I, Foundations, Cambridge University Press.
5) Sakurai J.J., 1967, <i>Advanced Quantum Mechanics</i> , Addison Wesley Publishing Company Inc.	13) John David Jackson, <i>Classical Electrodynamics</i> , 1962, 1975, John Wiley & Sons, Inc.
6) Ryder L.H., 1985, <i>Quantum Field Theory</i> , Cambridge University Press	14) Mencuccini C. & Silvestrini V., 1988, <i>Napoli, Elettromagnetismo e Ottica</i> , Liguori Editore,
7) Mandle F. & Shaw G., 1984, <i>Quantum Field Theory</i> , Chichester, New York, Brisbane, Singapore, John Wiley and Sons Ltd	15) Crawford. F. S. Jr, 1966, <i>Berkeley Physics Course, Vol. 3, Waves</i> , U.S.A., McGraw-Hill book Company
8) Greiner W. Bromley D.A., 1990, <i>Relativistic Quantum Mechanics, Wave Equations</i> , Berlin Heidelberg New York, Springer Verlagh	16) Feymann R.P. Leighton R.B. Sands M., 1965, 1989, <i>The Feymann lectures on Physics. Vol. 2</i> , California Institute of Technology

Questionnaire and interviews: We comprised 8 questions (Table 2) to be responded in writing or orally by a sample of theoretical physicists (researchers-teachers and PhD students) of the Bologna University and the Hebrew University of Jerusalem. The interviewed chose the modality they preferred for the answers.

The aim of the questionnaire was to clarify:

- the role played by the KGE in the modern physics knowledge as perceived by a professional, whether it reflects the contents of the textbooks or experts elaborate a personal position about the role and the meaning of the KGE;
- whether and how the aspect of cultural knowledge of modern physics (in the sense suggested by the DC approach) is perceived and eventually addressed by professionals engaged in physics research.

Table 2. Klein Gordon Equation - Questionnaire

<p>1) What is, in your view, the importance of the KGE in presenting modern physics to students?</p> <p>2) The KGE is often only briefly mentioned to students. Does it correspond to your experience? If so, what are the reason(s) for that (beyond the lack of time)?</p> <p>3) The story of KGE tells us about the attempt to interpret the KGE as a relativistic equation for the wave function of a particle. Later on, the KGE was used within the framework of quantized fields. Are there any other relevant applications of the KGE?</p> <p>4) The d'Alembert equation $\square f=0$ and the KGE $\square f =m^2f$ are rather similar in form. Do you ascribe any importance to this similarity? Please explain.</p> <p>5) The failure of interpreting the non-quantum KGE as an equation for relativistic wave function historically led to the abandonment of this equation. In the courses of physics, d'Alembert equation is taught as a wave equation of electromagnetic field, and Dirac equation is taught as giving relativistic wave function to account for electron and calculate its probability density.</p>	<p>Both these equations are taught later again in the advanced context of quantized fields. The KGE appears then too. Consequently, the KGE seems to be valid only in the context of quantized fields without any classical meaning. Could you see any special reason for this lack of symmetry and the unique area of validity for the KGE?</p> <p>6) Do you think that considering the same equation across different areas of validity, like in classical theory and in quantum theory, or in quantum theory with and without field quantization, and comparing between the uses of the equations presents a good pedagogy?</p> <p>7) In general, would you consider teaching physics while bridging and comparing between the same concepts (equations) in different contexts (classical, quantum, quantised field) to be a valid educational approach, or you prefer to avoid such approach to prevent students' confusion?</p> <p>8) In your view, at what level of instruction the KGE could or should be taught?</p>
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Results

The status of Klein Gordon equation in physics

The results of the analysis regarding the KGE from a Discipline-Culture perspective allowed us to clarify the *status* of Klein Gordon Equation in different fundamental physical theories elaborated as *discipline-cultures*. The analysis led to the conclusion that:

KGE belongs to the *periphery* area of knowledge of the non-relativistic quantum mechanics (QM): at the beginning of the last century, 1926, the pioneers of QM (E. Schrodinger, O. Klein, V. Fock, J. Kudar, W. Gordon, Th. De Donder and H. Van Dungen) tried to force changes in the formal apparatus of the new theory in order to adjust it to the requirements of the theory of relativity and to attain the Relativistic Quantum Mechanics. This step had to establish a relativistic equation for the wave function of the electron. The methodological assumptions led them, almost naturally, to conclude that the best candidate for this purpose was the KGE. It, however, appeared to be inadequate choice because the equation failed to provide the positive probability density in prediction of space location for the relativistic particle. For this reason, the KGE was abandoned and so within the DC structure it should be considered as a *periphery element* of the non relativistic QM: it contradicts the basic assumptions of the theory formalism regarding the wave function.

*An equation formally identical to the KGE** appears in the *body knowledge* of the Classical Electrodynamics: in several situations a physical system can be modelled as a fluid characterized by its charge - density (for example, in studying the motion of free electrons in the Earth ionosphere). When basic oscillations of the charged fluid are considered, in accordance to Maxwell equation, the KGE type of equation can be provided for the description of two entities: the components of the electromagnetic field in the medium (generated by the oscillating elements of

the charged fluid) and an abstract field which allows to construct the charge density in the problem. In this case, since the equation results from the application of the fundamental principles and laws of Classical Electrodynamics, it can be identified as belonging to the body knowledge of that fundamental theory.

*An equation formally identical to KGE** appears also in the *body knowledge* of the Classical Mechanics: the way followed by d'Alembert to derive his famous equation is well known (see for example Berkeley Physics Course, Volume 3, *Waves*, McGraw-Hill 1966). He considered infinite chain of coupled oscillators and found the equation for a vibrating string through going to the continuum limit. In the case that the oscillators are located in the gravitational field, the reaction force exerted on every element of the system is due not only to the elastic springs but also to the gravitational force. Running again the step proposed by d'Alembert one is led to the KGE. So, corroborated also by an historical event, the KGE can be identified as an element in the *body knowledge* of the Newtonian mechanics.

The KGE belongs to the *nucleus* of the Quantum Field Theory: as already mentioned, the quantum Klein Gordon field is related to the description of massive, relativistic and spinless particles (such as pions) and, together with the EM field, the process of quantization for the Klein Gordon field establish a paradigmatic case of quantization of any other field.

* By the “equation formally identical to KGE” we aim at stressing the fact that despite of the formal identity of the structure of the equation appeared in the considered contexts, Klein and Gordon did not write it in that meaning, since they never addressed the mentioned domain of physics knowledge. As already mentioned, they wrote the equation solely to account of the relativistic particle behaviour.

The status of the Klein Gordon equation in physics teaching

Analysis of the textbooks

The results obtained by the analysis of the textbooks using the DC perspective showed that the KGE was:

- extensively treated in the context of quantum mechanics. There, it was identified as a *periphery element* of the non relativistic quantum mechanics and as a *body element* – within the Quantum Field Theory.
- usually ignored in Classical (Newtonian) Mechanics and in Classical Electrodynamics, although could be identified as a *body knowledge element* in both theories.

Notable exceptions to this situation were the textbooks by Jackson, Berkeley course and Ryder (see table of textbooks), which provided important hints to the nature of the equation within the Newtonian and Electrodynamics theoretical pictures.

Interviews and questionnaire to physics experts

From the interviews and questionnaire to physics experts two different standpoints can be clearly distinguished:

- in most cases experts expressed positions very similar to those that were presented in the textbooks: the KGE is universally admitted as a subject in the theoretical description of particles in the Relativistic Quantum Mechanics and in Quantum Field Theory, but it is generally ignored in the other contexts: Classical Mechanics and Electrodynamics. In cases the equation did appear in certain context, it was never related to other appearances of the same equation in other domains of physics.
- a few notable cases of experts showed what is called within the DC model a “*cultural knowledge*” about the KGE. Some of them stressed several problematic issues in the regular university presentation which they thought requires revision, introducing a retrospective reflection. The cultural knowledge, necessary to relate

the KGE between several disciplinary contexts, was part (and considered by themselves as part) of their research professional interests and skills.

Results of the analysis: KGE as an exemplary topic in QFT teaching

With regard to the results of the analysis of the textbooks and the main trend in the knowledge shown by the physics experts, the case of Klein Gordon equation appeared to be a *specific topic* that however allowed us to point to the *general features* of the way in which the Quantum Field Theory is introduced and taught. In particular, the current teaching of the Quantum Field Theory shows, in general, that teachers:

- *avoid* discussing relationship of the considered subject to different areas of physics knowledge and ignore the *interference* between the different disciplines: Classical and Quantum Field Theories, Relativistic Quantum Mechanics and Classical Electromagnetism.
- *focus* on *technical details* and avoid revealing to the students the conceptual meaning of mathematical formalism. Thus, in the procedure called *canonical quantization* (the common way to introduce the QFT framework) the ontological differences between the objects involved (that is the different fields which are “quantized”) are normally ignored.

On the basis of the results obtained we arrived to conclusion that the current instruction on the contemporary physics usually misses the cultural perspective to the presented disciplinary knowledge as was defined by means of the Discipline-Culture Model. The KGE case may illustrate that such instruction encourages a strictly *disciplinary* knowledge about the QFT and its isolation of from the rest of physics.

Cultural analysis of Klein Gordon equation

The cultural and educational analysis of the knowledge related the Klein Gordon equation could be summarized and represented as conceptual map (Figure 1). One can see here the path of conceptual (and historical) evolution of content knowledge by following the arrows in the clockwise direction. This map should be interpreted as following:

- 1) Although the KGE is addressed only in teaching the relativistic quantum mechanics and the QFT, its essential structure, being invariant can be found in other discipline-cultures of physics.
- 2) The comparison of such projections on the different domains of knowledge allows effective comprehension of the change of the physical meaning of solutions of the KGE equations, helping to described various physical objects. This is possible in describing the displacement of an element of a string in the gravitational field, in describing electromagnetic field inside a medium, as well as in the attempt to construct the relativistic wave function for the electron.
- 3) The change in the physical meaning can be put in direct relationship with the change of the mathematical and formal expression of the correspondent solution.

Starting from the Newtonian case (for whom a real function is sufficient to describe a displacement of an element of the fluid), the case in electrodynamics and the introduction of the electric charge, requires additional degree of freedom and the complex function is necessary. The processes of creation and annihilation of relativistic particles and the quantum values of the dynamical variables in Quantum Field Theory require further upgrading of the formalism. Instead of complex functions usually used for describing wave functions the operator-valued distributions are utilized.

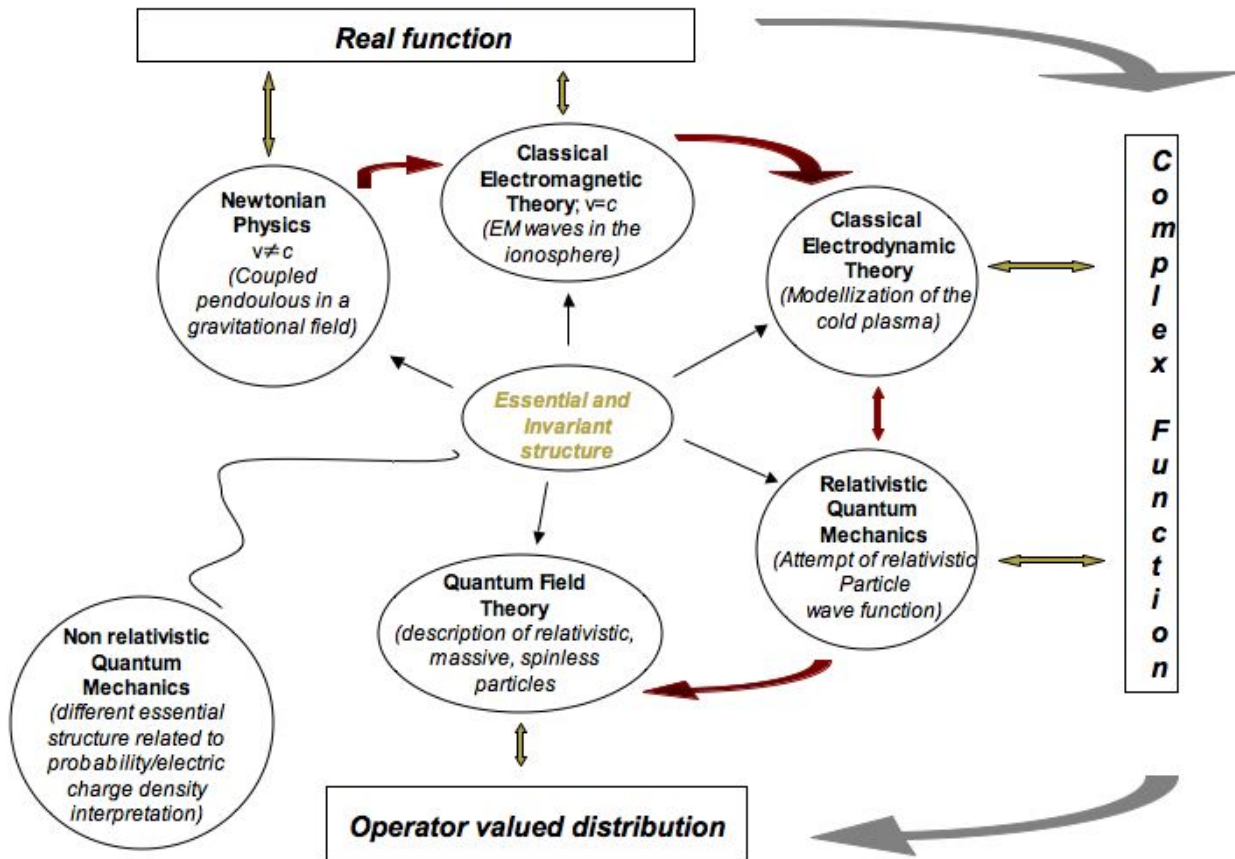


Figure 1. Cultural representation of the knowledge regarding the Klein Gordon equation.

This reconstruction combined in one picture, in our opinion, shows at least three aspects of cultural relevance:

- QFT is no more isolated from the rest of physics;
- Physics formalism is continuously kept under awareness by the learner and is related to physical interpretation;
- The model of objects and interaction in the QFT rises as a conceptual and formal refinement in connection to the phenomenological changes.

Note how the non relativistic quantum mechanics joins this framework. As already mentioned, the Klein Gordon equation can be derived, following the historical path, starting from Schrodinger, his non-relativistic equation and his attempt to obtain relativistic account for elementary particles by means of a wave function. The path followed and the assumptions made led physicists impose a strong change in the approach: from the non relativistic and probabilistic framework to the relativistic and non probabilistic one (we do not mean that the relativistic framework always denies probabilistic interpretation, see the Dirac equation). To express this change we related what called in the map *essential and formal structure* to the *non relativistic quantum mechanics* by the curved line emphasizing the difference.

Conclusions and Implications

We have applied the Discipline-Culture approach to consider the status of the KGE in teaching modern and contemporary physics in advanced university courses. The approach motivated us:

- to *clarify the cultural status* of the KGE in physics. The analysis revealed the KGE as a fertile ground for the conceptually rich teaching of physics through interrelating fundamental physics disciplines, and displaying the inherent connections between them. This teaching encourages cultural knowledge of physics and performs students' enculturation into physics;
- to *locate the shortcomings* of the common teaching of the advanced physics courses. The extreme prevailing of formalism over conceptual knowledge causing on behalf of the students lacking of awareness about the points critical for their genuine understanding of the subject matter

As implications of the study for Science Education Research, we retain important to underline that the present study explored “extreme territories” of Physics Education. KGE is not a subject of primary or secondary school and even a subject of general university courses. Only the student who dedicates their curriculum at the study of theoretical Physics meets the KGE: it is, without doubts, a very advanced topic. Nevertheless, the study here reported can be considered an example for showing that arguments and awareness produced within the field of PER still hold and define the identity of this research field with respect to other fields, such as Theoretical Physics or Philosophy of Physics.

More specifically, the physics re-construction presented here – and carried out applying a model elaborated within PER – is also strongly coherent with the “model of longitudinal development” tuned up within the Italian project PRIN_F21 (2004), coordinated at national level by P. Guidoni (Guidoni, Levrini, 2008).

The model points out criteria for coherence and crucial steps that allow the cognitive potential of the pupils to be progressively exploited and tuned to the construction of Physics knowledge along the pre-university curriculum (from kindergarten to upper secondary school). According to the model, knowledge's evolution is seen as a progressive (more and more powerful) process aimed at extending, “re-investing”, explicitly revising interpretative formal structures and models when enlargements and/or changes of the phenomenological basis are enacted or when explanatory schemes clash with each other in “border problems” (Levrini et al., 2008).

The KGE reconstruction summarized in Fig.1 follows the same dynamics and extends it at advanced university level.

The fruitful resonance between the DC model and the model of longitudinal development realized in reconstructing KGE is another way to stress the educational and cultural potential of the analysis carried out and its specificity with respect to analyses that could be carried out from other research perspectives.

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HOW DO PRE-SERVICE SECONDARY SCIENCE TEACHERS STRATEGIZE THEIR PEDAGOGY TO TEACH FOR CONCEPTUAL CHANGE

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Abstract

This study describes how a cohort (22 trainees) of pre-service secondary science graduates designed a unit of teaching. The unit of teaching they were required to plan and deliver had to describe and evidence how they uncovered the alternate conceptions their students held. They also had to illustrate with their lesson plans how they intended to overcome their pupils' incomplete or flawed ideas. After teaching for conceptual change they then had to deliver their lessons and assess how successful (or not) their approach had been.

Introduction

The research approach taken was that of an appreciative enquiry (Bradley, 2006) whereby the trainees; i, reviewed the understandings of the pupils in their class before teaching them; ii, considered what they should come to know, appreciate and understand; iii, designed a series of learning experiences to address the alternate conceptions and then; iv, assessed whether their pedagogic approach had been successful in achieving the learning aims.

Background, framework and purpose

The assignment which provided the evidence of trainee's practice from their lesson plans, was required by the pre-service teachers to fulfil the requirements of the subject specific module (TE4060) that all teacher education postgraduates at the University of Wolverhampton (UoW) have to complete to achieve qualified teacher status at master's level. The analysis detailed here arises from the first iteration of this module during the academic year 2007-8 as part of a strategy to ensure that Masters' level skills of critical analysis were appropriately developed through this assignment.

As the assessment of the module was at level four trainees needed to apply skills as reflective practitioners developed during earlier modules to evaluate critically the extent to which their approach facilitated pupils' achievement of learning. Trainees maintain a reflective journal and set of field notes throughout their various teaching attachments and draw on these to inform and add detail to these assignments.

Rationale

Teaching secondary school children about science is often very challenging because ".....students do not come into science instruction without any pre-instructional knowledge or beliefs about the phenomena and concepts to be taught" (Duit & Treagust 2003 : 671). As Driver et al (1994 : 1) indicate "many of the conceptions which children develop about natural phenomena derive from their sensory experiences" and as Ausubel (1968) has infamously prescribed: 'The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.' This paper focuses on how trainee secondary science teachers explored the nature of childrens' scientific understandings before being taught a unit of work. The various ways that they

subsequently taught to address the alternate conceptions they uncovered, are also described and analyzed with four key learning frameworks in mind; behaviourism, constructivism, social – constructivism, (Scott, P., Asoko, H. & Leach, J. 2008) and socio-cultural perspectives (see Figures 1,2,3,4).

Methods

The research is carried out within an interpretive paradigm (Cohen, Manion & Morrison 2007 : 21) and the study of trainee secondary science students assignments that they were required to engage in was an inquiry approach (Clarke & Erickson, 2003). The trainees were scaffolded, through the assignment requirements, to review their learners' understandings of a science topic they were about to teach as well as design lessons to support conceptual change. They also had to disseminate their enquiry findings in three ways. The first was somewhat formative through a verbal report to their peers in the trainee cohort. In this presentation they indicated the subject area of their teaching focus (see Table 1), provided a brief outline of alternate conceptions uncovered and offered a synopsis of their approach to deliver the planned lessons. The second mode of dissemination was through conversation with mentors or a presentation to their school experience colleagues (not detailed here); the third method of dissemination was the formal assignment required, to pass Module TE4060, to gain (30) credits at masters level, as a qualified teacher. This work arose through development of masters level modules that were required alongside the practical aspects of the one year post-graduate training course.

Module TE4060 is centred on Subject-Specific Pedagogy which requires the trainee teachers to :

- Identify and plan a sequence of lessons drawing on innovative teaching strategies [informed by the exploration of students' misconceptions].
- Teach, assess and evaluate the sequence of lessons.
- With one focus class they described how they deepened their knowledge and understanding of one aspect of teaching and learning in their specialist subject.

It is in the lesson plans included in this assignment that provided the substantive evidence for this study.

Table 1 : Indication of range of focus for Subject Specific Pedagogical study.

Areas chosen for focus	Proportion of cohort (%)
Forces and Motion	23
Respiration	9
Sound	9
Food and Digestion	5
Electricity	18
Light	5
Particles	5
Heating and Cooling	9
Burning	5
The Rock Cycle	5
Human Reproduction	5
Scientific investigations (HSW)	5

The trainees' presentations to their peers provided an initial, qualitative, indication as to what they had uncovered about alternate conceptions and how they had intended to teach to support their pupils development in coming to understand the intended outcomes of their teaching. The descriptions of their approaches indicated whether they were tending to provide behaviourist (Skinner, 1968), constructivist (Piaget, 1929), social-constructivist (Vygotsky, 1978) or socio-cultural (Rogoff, 1990) learning experiences for their pupils.

The methods that the trainees initially used to assess their learners' understandings before delivering their carefully designed teaching units usually included formal class tests or informal small group discussions.

Four students chose to use two different strategies, usually a quantitative one (some kind of formal test, either pre-designed by a course, previous SAT questions or specific topic questions), complemented by a qualitative approach. The informal discussions often provided in-depth information about why pupils held alternate ideas, e.g.: 'Sound can travel through a vacuum because vacuums are noisy', or 'Sound can not travel through liquids or solids because it needs air'. Analysis of pupils' responses to the tests and discussions were then used to inform the nature of lesson activities and focus of teaching to address these.

One trainee who recognised how young people confused breathing and respiration provided sensory experiences to emphasize differences between the processes. He included a kinaesthetic activity modeling the passage of oxygenated blood (using red balloons) and de-oxygenated blood (using blue balloons) held by pupils moving around a tennis court size circulatory system. This student also used the very visual evidence of the 'screaming jelly babies' to illustrate different forms of energy and the prominent idea of energy transfer when food is combusted in the respiratory process.

Another trainee was concerned about the order in which things are taught and carefully sequenced (and entitled lessons as questions) to organise activities to be logical in the way she taught about burning. She began ordering the topic in the following way:

“Lesson 1 : Does a burning candle use up something in the air?

Lesson 2 : What is produced when a candle burns?

Lesson 3 : When a candle burns on scales does the mass change?.....”

Trainees often used sensory demonstrations of spectacular phenomena or visual iterations to present concrete evidence of a process or principle to persuade (Mayer, 2002) their pupils of a more scientifically accurate idea.

It appeared that many of them empathized with the learners perspective illustrated by this trainee statement in her assignment :

“Key principles for my teaching sequence:

Activities that I use will involve pupils interacting with the ideas that I have presented to them, and will hopefully make them think about the concepts (active learning).

Time will be given in lessons for pupils to discuss their ideas giving pupils a chance to articulate and challenge their own and others ideas and hopefully further develop their thinking.

I will attempt to disprove pupils' misconceptions at the beginning of the teaching sequence, before new ideas are introduced.”

To qualitatively analyse the way the trainees organised learners' experiences in lessons, their plans were scrutinised. What the learners were expected to do was contrasted with the key indicative behaviours of four views of learning (behaviourism, constructivism, social-constructivism and socio-cultural). These perspectives of learning, described in Figures 1,2,3,4 are developed from McGregor (2007:52-61).

The lesson plans submitted in the assignments, designed to address alternate conceptions of the pupils, were then scrutinized. Each key activities in the trainees' plans were mapped against the four models of learning and the incidences of those intended were tallied for each lesson in the topic sequences. For each activity in the lesson plans corroboration between two tutors (on the course) was sought. Agreements of the nature of actions was then cumulatively noted in tabular format (see Table 2).

The frequencies of use of each approach to learning were then analysed to explore the nature of relationships between the more academic students (who attained well on the written and theoretical aspects of the course) and those who were more practical and achieved the highest grades for teaching performance in the classroom. It was postulated that those students with more academic acumen, having scrutinised the literature more comprehensively, would recognise the value in developing opportunities where, as Adele, a high achieving trainee wrote '...pupils confidently share their ideas and due to the safe environment this creates, they are not afraid to ask their peers for help. It enables pupils to listen to others, evaluate and rethink their views, which reflects the conceptual change model (Stepans, 1996)'. The results of this analysis, however, are not reported here due to lack of space.

Facilitating opportunities for pupils to check out their understandings with each other, seek re-assurance from a peer that they have developed appropriate conceptions or even affirm or refute somewhat tentative ideas held by learners are key processes underpinning social construction. Providing space to rehearse thinking and understanding was expected to be regularly included (if only as reflective episodes) in lesson plans.

Active acknowledgement of socio-cultural aspects of learning and engineering pairings or groupings for novice and expert to mutually support each other, and supporting development from legitimate peripheral participation to full engagement in scientific activities in a knowing way (Lave and Wenger, 1991) was not anticipated to be regularly planned for. Organising learning to be more than just conceptual-mental (Lave, 2008) and enabling learning in science as an everyday, accessible social practice by developing scientific skills within communities of learning was not expected to be commonplace. The study carried out here analysed the planned intentions of the students (not the actual enactment of the lesson plans although their reflections on the extent of successful teaching are included). Therefore those trainees who intuitively responded to their learners' needs to support collaborative learning and those who paid attention more spontaneously to socio-cultural influences will not have been recognised using this analytical approach and may be under reported.

Results

Generally there was significant use of behaviourist strategies (see table 3).

Table 3 : The frequency of different types of learning activities used by 22 trainees planning to teach for conceptual change.

	Behaviourist activities	Constructivist activities	Social constructivist activities	Socio-cultural activities
Number of different learning activities	274	209	70	0
% learning activities	49.5	37.8	12.7	0

Almost half the activities the trainees planned for (albeit good, effective demonstration, illustration, experiment or multi-media presentation) were guided observations that pupils then copied notes about, completed cloze procedure writing about, responded to related comprehension questions or answered recall questions on, all offering a rather behaviourist learning experience for the children. These kinds of approaches constrained pupil development, did not encourage discussion or exchange of views between learners, but aimed to convey clearly 'correct' scientific principles. Over a third of the activities provided a more interactive experience for the learners, offering more constructivist opportunities for learning. These activities were more usually small groups carrying out

experiments, practicals or specific tasks. They also included pupil-assisted demonstrations, but essentially offered opportunities for individuals to postulate about observations, cogitate over phenomena and develop personalised meaning from data and evidence.

Social constructivism, offering more openings for shared discussions and debate about juxtaposed understandings, appeared to be applied much less (12.7%) and socio-cultural strategies were not used. There appeared to be more use of social constructivist teaching strategies in the lessons of the trainees who were more capable in their practical teaching performance than those who achieved higher academic achievement. This was not anticipated as those more rigorous in their academic work were assumed to recognise the value of social interaction and the influence of socio-cultural factors in shaping childrens' understandings in science. There was very frequent use of verification-type practical work (Bates 1978) or prescriptive approaches (McGregor, 2003) that enabled the students to interact with materials to support personalized construction (Driver 1995) or teacher demonstrations of phenomena in a concrete (Adey & Shayer 1981) way.

Often the practical activities selected provided excellent demonstrations or representations of scientific phenomena, but few regularly utilised social constructivist approaches, in carefully planned ways, involving small class discussions and group work. There were varied barriers, though, to trainees developing pedagogic approaches that they had initially envisaged after ascertaining their students' conceptual shortcomings. Several of the students indicated a lack of time in lessons to devote to more small group work, informal discussion, and time to discuss alternate ideas about evidence or observations presented. Several also indicated that the departments within which they trained did not spend a significant time addressing what they knew were particular difficulties for pupils in their scientific understanding.

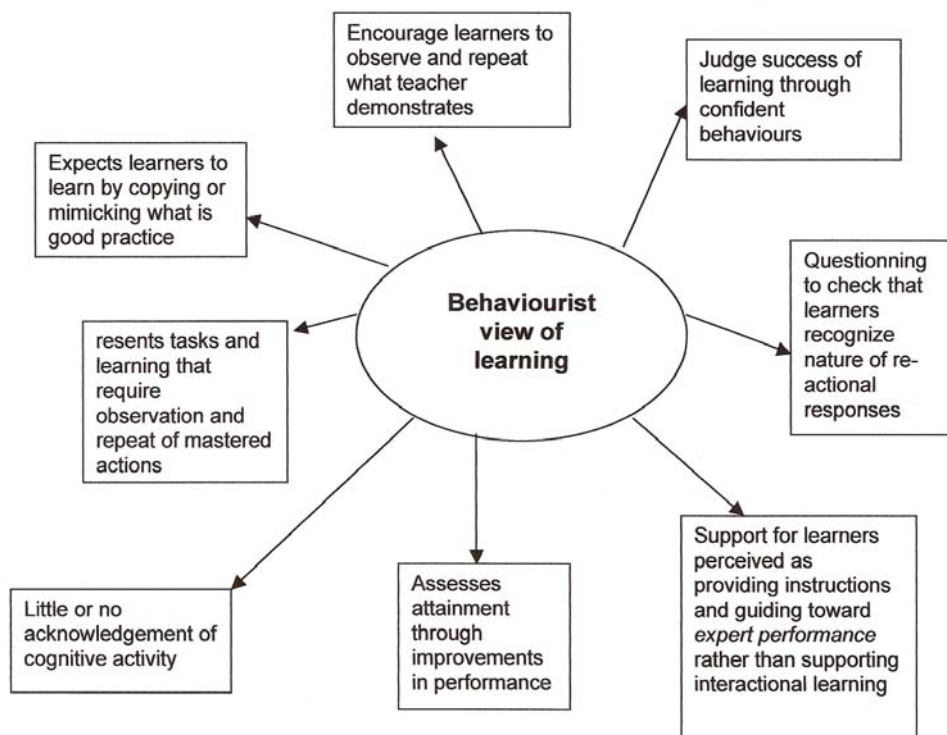


Figure 1 : Teacher behaviours and expectations implied by the behaviourist view of learning (McGregor, 2007).

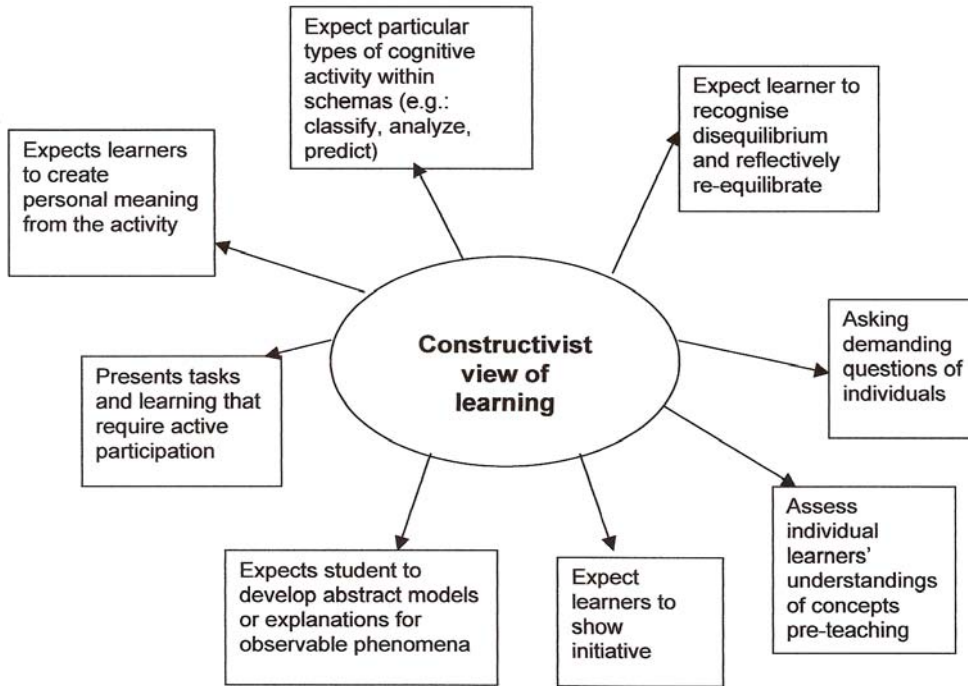


Figure 2 : Teacher behaviours and expectations implied by the constructivist learning theory (McGregor, 2007)

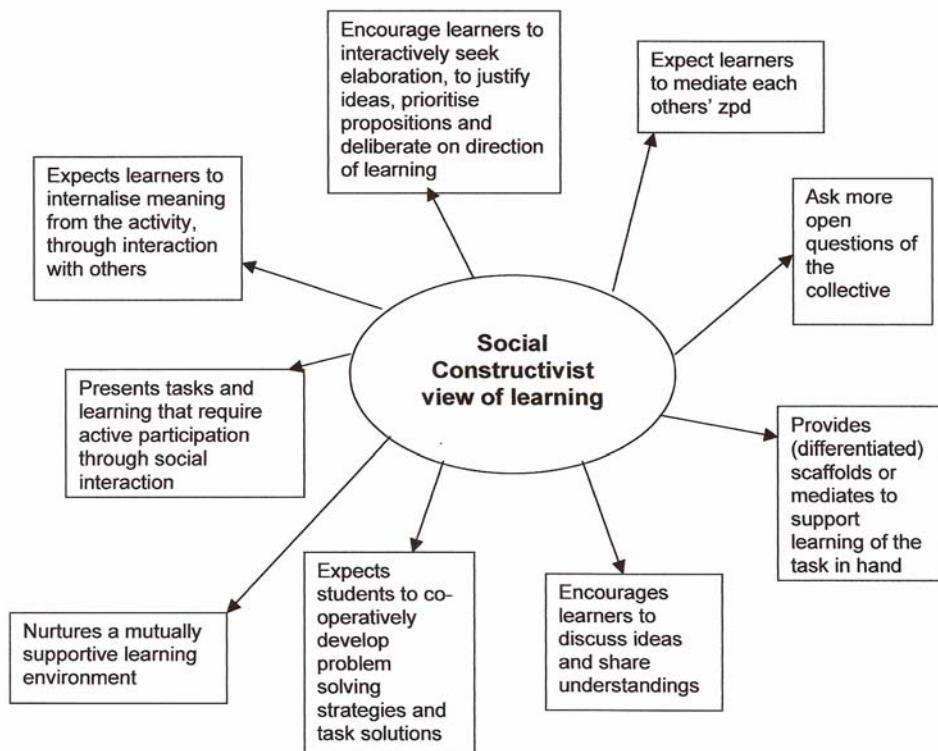


Figure 3 : Teacher behaviours and expectations implied by the social constructivist view of learning (McGregor, 2007).

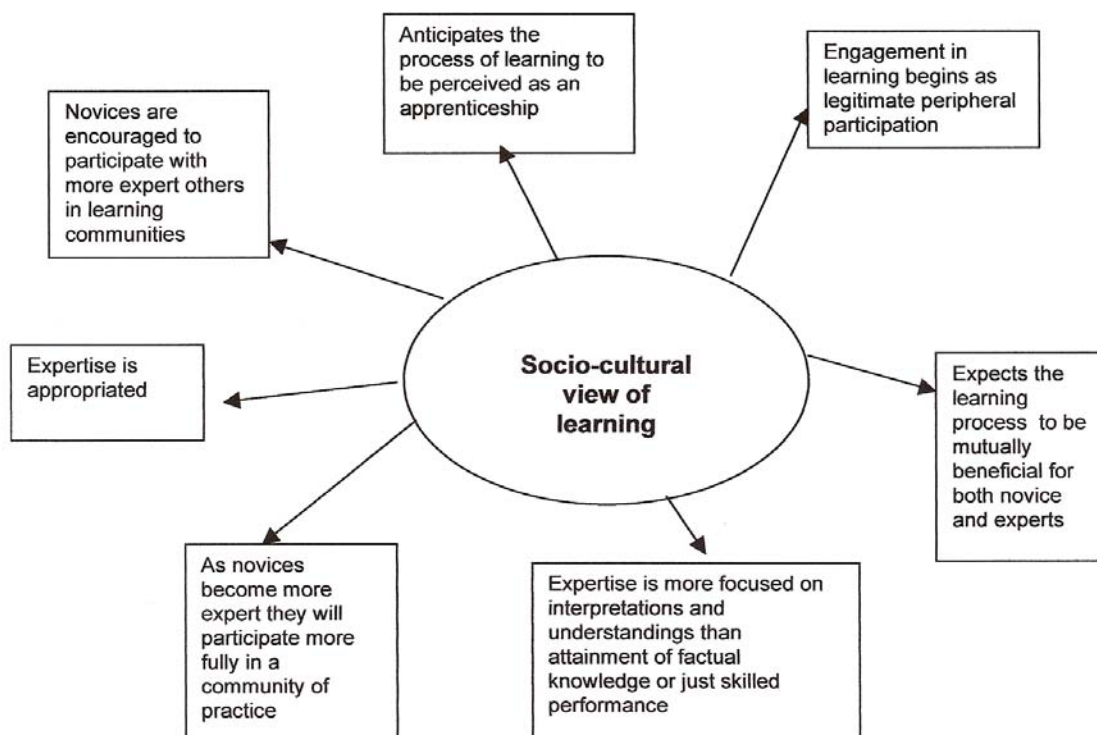


Figure 4 : Prominent teacher behaviours and expectations implied by the socio-cultural theory of learning (McGregor, 2007).

Conclusions and Implications

There is clearly little or no extensive evidence of the more inclusive pedagogic strategies that embrace socio-cultural techniques (e.g.: novice and expert working collaboratively for mutual gain). Most trainees clearly demonstrated phenomena for their pupils to observe happenings, events and evidence. However, the ways that pupils were directed to consolidate (through report writing) on these experiences was often very prescriptively framed.

Several trainees ‘directed’ pupils in their plans to do things. Quite a few trainees also used cloze procedures or asked closed recall type questions to ascertain learning. This was indicative of a behaviourist approach to learning.

Many used peer assessment of written answers to questions, reiterating through responses to recall questions exactly what was expected in terms of the correct scientific principles and concepts that should be routinely learned.

Fairly frequently, though, trainees expected their pupils to observe, reflect and cogitate on evidence presented. In this way they were applying a constructivist approach to the learning activities in their classroom. Although some of the more capable trainees, provided opportunities in their lesson plans, for pupils to freely exchange views and reflections on the learning activities, few regularly invited pupils to share their feelings, thoughts and questions on the topic or issue in question. There did not appear to be frequent opportunities for pupils to choose the direction of an enquiry, investigation or independent exploration.

Many trainees used testing approaches to ascertain pupils’ understandings. Several carried out informal, in-depth conversations with children.

There appeared to be qualitative indications that beginning teachers in secondary science, although they frequently offer motivating and engaging demonstrations or intriguing activities for their students to observe or

carry out, they tend to organise their teaching to provide mostly constructivist learning opportunities when intending to support conceptual change. The semi-quantitative analysis, that provided numeric indications of the regularity with which different types of learning opportunities were offered, also indicated trainees pre-dominantly provided teacher-demonstrations or computer-generated animations for pupils to experience science and develop their individualised meanings.

Therefore it appears there were fewer social-constructivist opportunities than were anticipated, provided for pupils by trainees towards the end of their preparation for teaching, and more behaviourist learning approaches than anticipated. Even though the trainees' literature reviews introducing the assignments, illustrated that the trainees understood research which illustrates that small group working to discuss and exchange ideas were key approaches to support conceptual change, there were fewer opportunities of this kind planned for in their lessons.

There are obviously many implications and issues to be considered and addressed. Some of these include; 'Do trainees usually feel confident enough to be more socially constructive by the end of their practice?'; 'Should the course provide more learning theory training?'; 'How should trainees be guided pedagogically to support students conceptual change?'; 'Should there be more continuous professional development of secondary science teachers after they have qualified?'; 'How far do science subject managers consider, plan, support and evaluate success in teaching for conceptual change in secondary comprehensive schools?'

In discussions with trainees on their teaching practice, mentors it seems are sometimes more concerned with the pace of coverage than the quality and depth of learning, and that telling pupils what they need to know is an efficient way to teach and address misconceptions. This is echoed by OfSTED (2008) in the review of Successful Science 2004 - 2007 where they state that, '...in too many [...] secondary schools teachers were mainly concerned with meeting narrow test and examination requirements and course specifications. This led them to adopt methodologies which did not meet the needs of all pupils or promote independent learning.' Opportunities for trainees to develop more socially inclusive and interactive approaches to learning are thus constrained, as it appears that in many schools the intention is to frogmarch students "across the scientific landscape with no time to discuss any of the ideas or their implications" (TLRP, 2006).

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GUIDING THE PHYSICS STUDENTS TO THE DOORSTEPS OF MODELLING THROUGH THE GATEWAYS OF ASSUMPTIONS AND ANALOGIES

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Abstract

For teaching introductory physics at the middle school, teachers do need to take resort to suitable analogies from the surrounding. The analogies should be culture and geography specific. The conventional analogies need to be judiciously used. However the analogies have their own limitations. Assumptions are necessary for building up the model of a physical situation and its analysis of its behaviour quantitatively. The assumptions are made to take care of the complex physical situations simpler, sometimes ignoring the finer aspects. Experiments are conducted to check back the veracity of a model and the assumptions on which the model is based. The success of a model also depends not only in describing and explaining a physical situation but also on its ability to predict an experimental outcome done on that situation. The finer experimental measurements can expose the limitations of a model and a closer look on the assumptions is called for. This paper presents a suggestive approach with suitable illustrations from the experience how to interweave the three aspects of physics teaching viz: analogies, assumptions and mathematical modelling to make the learning a comprehensive one.

Introduction

Physics attempts to explain the phenomena in the physical world around us and tries to unearth the laws of nature. Physicists try to frame a mathematical relation among the physical quantities involved in the form of a law that makes the application and use of the rule handy. Once the laws and principles thereof are well understood they are used for the prediction of expected observations. Technology tries to exploit the laws to come up with newer innovations and the science and technology proceed hand in hand. The students are exposed to the principles of physics quite early in their school life and that helps them to understand logically a number of observations in the physical world around them at a reasonably early age (Young, 1988). The analogies from real life with which the students are even more familiar have been proved to be very useful tools for teaching the subject at an initial stage. However it needs to be mentioned in this connection that in the teachers' training programmes the similar concepts demand different mode of presentation (Harlen, & Elstgeest, 2000). This is because of the fact that a teacher as an adult and a matured person with the background knowledge of a particular subject wants to look at the analogies in a somewhat different way. And that is why the analogies, models and of course the laboratory experiments form a few very important and fundamental components in physics for understanding the real world around us.

Physicists make a significant number of assumptions when they develop any theory or model to explain or to describe a physical situation. This is mainly because of two reasons. First in the real world with large number of factors, big or small, are responsible for the way the things appear to us. These factors, if taken together make the dealing of the situation quite complicated and the school students find it difficult to comprehend. Secondly through some assumptions that are not expected to affect the results in a very significant way one can find a convenient way of developing a model for a physical situation. This aspect of assumptions incidentally is not being highlighted in the classroom. That way the assumptions are also integral part of physics teaching and the learning process.

Analogies are very useful for teaching early physics but at the same time it has to be kept in mind that after a certain stage the analogies are indeed questioned by the students pointing out the mismatch between a physical situation and the analogy used for explaining it. This in a way is not surprising and it indicates a healthy trend about the understanding of the students who can take a note of the inadequacy of the analogies. That prepares the stage for modelling of the physical situation where one no more depends on analogy but stresses on a language linked with mathematics to explain the observations. And the modelling of a physical situation can be done with the help of certain assumptions since the real life is quite complex and it may not be possible to take into consideration all the finer aspects to start with. In this paper an attempt will be made to identify the approach that will take care of better learning of physics based on the modelling of the physical situations underlining the roles of the analogies and assumptions.

Analogies as useful tools

Up to the middle school level the teachers cannot use much of mathematical relationships or models to deal with the different physical situations because of two reasons. First the mathematical skill of the students do not prove to be adequately developed secondly students prefer to know about the physical phenomena around them in such a language that strengthens the feeling that physics is a real life subject. And that cannot be done with mathematical language at that stage. So the analogies appear to be very useful for that stage (Klenk, Forbus & Kenneth, 2006). Students can actually visualize a situation if a suitable analogy is presented (Chakrabarti, 2006). In physics we deal with a large number of macroscopic observations, analyze their characteristics and try to correlate them with the microscopic behaviour of the system that is not always visible with unaided sensory organs or even with some instruments. For example, when we introduce Charles Law and Boyle's law they look like empirical laws and we cannot present the kinetic theory to describe the molecular behaviour linked with, say, the temperature of the gas. Similarly we can state and explain Ohm's law and can design experiments to show the validity of the law. But we need to pick up the analogy of water flowing through pipes of different cross sections to highlight the significance of resistance. Or, for that matter a teacher can be more innovative in choosing some similar analogy. One can only try to point out the similarity between the flow of water and current flow constituted by the motion of the electrons moving through a conductor but cannot show it as such. If we further want to explain the electrical conductivities of different types of solids, viz. good and bad conductors and semiconductors then we need to present it through the band theory. This is once again a proposition that involves mathematical modelling and only the use of analogy fail to drive home the important aspects of the situation.

Limitations of analogies

Though a very useful too yet the overstretching of analogies is likely to be counterproductive. That is why the analogies are indeed useful while initiating a concept though the explanations sometimes remain incomplete without the suitable mathematical language and a model thereof. Moreover when the students move to say 11th or 12th grade (16-18 years) they raise excellent questions pointing out the inadequacies of the analogies those have been rather comfortably used in lower classes to drive home certain points at that stage. And as such there is no reason that those analogies to be discarded altogether as they serve the desired purpose only up to a certain level.

Some researchers have pointed out that the students come to the class not with a blank mind. They do have some concepts in their mind about the happenings around them in the physical world. These concepts may not lead to the consistent explanations of the physical situations but should not be termed as 'misconceptions' rather should be called 'alternative conceptions' (Ramadas, Kumar & Barve, 1996). That is why the analogies need to be very critically chosen. And of course some simple demonstration experiments help us in this regard. Moreover the selection of analogy should take care of the social and geographical social, may be the economic contexts of the learner. For example if a teacher chooses the functioning of an expensive gadget as an analogy to drive home a point he or she may find it difficult to make the students visualize as most of them may not be familiar with the functioning of that gadget. So a teacher needs to be innovative and careful in this regard.

Handling physical situations through modelling

Modelling is an integral part of physics teaching–learning process. The main purpose of modelling lies in the fact that through suitable modelling we can actually handle a physical situation in a much comprehensive way (Edwards & Hamson, 1998). A model is normally considered to be a good one if it can mathematically calculate and predict the outcome of an event that can be experimentally verified. But a very important aspect of model lies in the fact whether it can lead the learner’s process of analysis in the right direction. This is not an easy task as it has already been pointed out that the learner’s thinking is not only governed by his or her level of learning but on the learner’s social, economic and geographic surrounding. That in a way tells us that physical principles may be universal but there is not a single universal prescription for presenting them before the learners. The models that we use in physics are meant to serve a few specific purposes. A model is expected to help us in describe a physical phenomenon, explain a physical phenomenon, predict a new physical phenomenon and of course to have a deeper understanding of the physical phenomenon (Etkina., Warren & Gentile, 2005).

Moreover a model is expected to lead us to a physical situation that is consistent with the logical framework and theory and with the experimental observations [8]. For example, when Bohr developed the model of hydrogen atom he had to take care of the explanation of the experimental observations of on hydrogen spectrum that Balmer made more than 25 years back. The model Bohr proposed took care the consistent explanation of that series. In the process he had to introduce the so-called ad-hoc postulates that later on proved to be consistent with the quantum theory. So with the help of a model we expect not only to explain the observations but also to generalize the physical principles and make logical prediction of the outcome of an experiment. So a model is developed to take care of several purposes.

Models can be simple as well as complex particularly when we want to make that more and more realistic. Initially say at the high school one should try to introduce only very simple mathematical models but one has to see that the students are taking the concepts and the necessity of model building by heart. Let us take an example to illustrate this point. When we introduce the undamped simple harmonic motion (SHM) students can always point out that the results do not conform to the real life situation. But what a teacher can always point out that the inclusion of damping in the physical situation will not only make it a realistic one but will make the mathematics a little bit complex. But at a certain stage once the students have developed that much of skill for handling second order differential equation with constant coefficient we can actually bring about a solution that much more realistically represent the actual observations. So basically the with more and more developed mathematical skill the modeling can be made more and more realistic and interesting.

In this context we can take a closer look at the simulations. Simulations are actually the outcome of modelling but the two should not be treated as the same (Teodoro, 2008) With the rather easy availability of computers and suitable software simulations have become easier and lot of things can be visualized easily. But this has the tendency of leading to unrealistic situations. In computer simulation one may try to put up parameters at one’s will but the realistic achievements of those in the laboratory condition this may prove to be extremely difficult even impossible. In a simulation say a magnetic field that is causing the deviation of the trajectory of an electron may be increased at will but in a real experiment that may prove to be a daunting, may be an impossible task. This may lead to a situation where the students may lose confidence in the process of modeling.

Implications of assumptions those precede modelling

Modellings of a physical situation is based on certain assumptions. These assumptions are actually made to make a complex real life situation simpler. But at the same time attention is paid to check back whether the assumptions involved make very large compromise on the results that we observe in reality. So the assumptions are to be chosen carefully and we always need to check back whether the developed model is giving us results consistent with the experimental observations within the acceptable limits. Incidentally there is an important gap in our teaching as far as the presentations of assumptions are concerned. Teachers quite often do not explicitly highlight the assumptions on which a particular model is based or the basis of the assumptions. And what will happen if the assumptions are removed is another important aspect that demands special stress. And at the same time it needs to be pointed out how the assumptions may introduce some sort of idealness in the physical situation and deviation from the real life scenario.

On the other hand we really cannot go for modelling without certain assumptions about the physical situations. For example, if we look at kinetic theory we assume that the collision between the molecules are elastic, molecules are point masses etc. none of which are so to speak, realistic. So a teacher will have to stress that kinetic theory leads to the Charles' law or Boyle's law only through certain assumptions. Since these assumptions lead to an ideal situation and in the process we get ideal gas equation. The real gas equation by van der Waals actually makes some corrections and presents us with an equation that is not very complicated yet can deal with the real gases with a reasonable degree of 'realness'.

Assumptions may be classified into two groups in the first type the assumptions lead to some sort of a model that is not only simple but predicts the results with a reasonable degree of accuracy. These assumptions become the integral part of the model. As an example we can talk about the model of thermal conduction through a solid. The assumptions that the molecules vibrate about their mean position and in the steady state the radiation loss remains constant if the surrounding temperature does not change; is a reasonable assumption and gives us good results till a the surrounding temperature remains within certain limit or the temperature difference at the two ends of the conducting rod is not too high. However when the conductivity begins to show temperature dependence the picture or the model we have developed through the assumptions begins to slip.

On the other hand second group of assumptions lead to a model that provides some immediate help in understanding but does not help in a big way in model building. The model that tries to explain the apparent observations may fail to deliver goods once finer observations have revealed newer features in the same system. One really needs to change the assumptions for this. For example in Mechanics where we deal with connected systems involving pulleys students make lot of interesting calculations assuming the pulley over which a string passes is massless and the string with connected masses at its two ends is inextensible as well as massless. Moreover the whole system is devoid of any friction. All these give us convenience of calculations on paper but if we want to do any experiment to realize those results the system fails to work as the number of assumptions have made it too ideal and it has deviated too far from the real situation. And it is not easy to apply corrections simply by removing the assumptions to make the model fit into the more and more realistic situation, rather an entire different approach is necessary. And the development of a real model for such situations is not all that easy.

Assumptions quite expectedly lead to approximate results. However the degree of deviation from the real situations varies. If it is not within the 'acceptable limits' we need to discard certain assumptions. The biggest utilities of the assumptions lie in the fact that they may be removed gradually and with newer formulation of the problem one can arrive at more realistic but complex results in most of the cases. So one can start with a simple model and go on checking the experimental observations with the help of it and try to improve upon the results by gradually changing them. In fact the computer simulation actually helps in bringing in about this sort of modification of the assumptions to be incorporated in developing a model.

Designing a research based approach

The research questions for the investigation of the understanding of the learners about the assumptions-based models, transformation of dealing of a physical situation from qualitative to quantitative approach needs to be critically framed. One can think of framing models of the same situations with some of the assumptions removed or some additional assumptions artificially imposed. Research questions need to be directed for having an idea how the learners reacting towards the assumptions and whether they find at least some of them contradictory in a particular situation.

Science educators often conduct workshops for the school students to augment what is known as the process of concept building. These are different from the classroom situations. These appear to be attractive opportunity for testing these aspects where we can take the immediate response of the students as an indicator. However the systematic building up of the concepts and their retention actually demands a somewhat different approach. If the non-formal approach beyond the classroom can be repeated for the same group of students it may prove useful. Since that is not always possible, some designing of the suitable teaching-learning module with research-based approach may be prepared for the teachers (Thornton, 2008). While framing an investigative module and the associated research questions that can be answered for the exercise has to be defined keeping some ground realities in mind. This framing of research questions, planning of a module for the investigation can only be identified through some prior activities like field tests, interviews with the teachers having experience of teaching these sections and from the inputs taken the experts etc. With wide variety of students having all sorts of background at different corners of the globe coming to a physics class to learn the same physics, some sort of a strategy can be evolved for the use of analogies and assumptions leading to the doorsteps of modelling of a physical situation.

Framing of a strategy is not that easy. Normally in the classroom a teacher does not get enough opportunity to elaborate all the aspects of a model including the assumptions on which it is based and the analogies that have been proved to be in adequate. Moreover there cannot be a straightforward prescription for driving home these points. Because of large number of factors from outside the classroom govern a learner's perception about the different physical situation a teacher is always faced with the problem of deconstruction of the misconceptions or so called alternative conceptions. So part of the strategy is expected to be universal while a part of it should be region specific.

Conclusion

The use of analogies and the subsequent development of models based on assumptions are indeed have become part of the strategy for not only teaching of physics but for the science subjects in general. Moreover the subjects like economics, sociology, geography, and management is getting more and more inclined towards this approach. After all, a physics teacher in the classroom always communicates the concepts and explanations before a group that has some idea about the physical situations that they have either encountered in real life or have visualized through real life experience. However these ideas significantly vary from student to student sitting in the same classroom. Through the framing of suitably designed research questions and survey questionnaire modules one can probe the impact of the approach among the students.

In an approach towards the modelling of a physical situation one will have not only to highlight the assumptions under which the model is a valid one but also the limitations of analogies that have been used. The students at the last two years of the high school and pursuing science study with physics as one of the subjects should be given a clear idea that the next level of physics is going to take this approach in a big way. And the totality of the approach is expected to make the task of the teacher systematic and possibly physics may become even more attractive to its learners.

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THE ORGANIZATION OF CHEMISTRY AS CONCEIVED BY UNDERGRADUATE STUDENTS – A STUDY USING CONCEPT MAPS

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Abstract

The increase of chemical knowledge presents a challenge to chemical educators. In general, undergraduate courses in chemistry organize this large amount of subjects around the five traditional areas of this science (analytical, inorganic, organic, physical chemistry and biochemistry). Their contents are usually presented independently, leaving to the student the task of making links and understanding connections between them. The aim of this paper is to investigate undergraduate chemistry students' conceptions about the interrelations among the several areas of chemistry. The study was made by means of concept maps, which were analyzed in the light of the "context areas" proposed by Goedhart (2007). Results suggest that a significant number of students have problems in expressing chemistry as an integrated body of knowledge. In general, students reproduced the division of chemistry in its five traditional areas. It was also observed that the curricular structure strongly influences how students conceive the relations among the areas of chemistry.

Introduction

During the past decades, chemistry has been experiencing major advances in terms of its limits and possibilities. Teaching institutions face the challenge to offer students up-to-date education dealing with the exponential growth in chemical knowledge (Gilbert, 2006). This is one of the major problems in discussions about the development of chemistry curricula. However, prior to curricular development, it is important to consider questions concerning the nature of chemical knowledge, its organization and interactions with other areas. In the beginning of the 1970's, the inadequacy of the classical structure of chemistry in describing this science was suggested:

“The classical structure of organic, inorganic and physical chemistry, which has largely determined how chemistry was taught, increasingly fails to reflect what is actually done in chemistry.” (Hammond and Nyholm, 1971, p. 9).

The aim of this work is to investigate conceptions expressed by undergraduate chemistry students with respect to the organization of chemistry as a science, especially focusing on how students conceive the interactions between the traditional areas of chemistry.

Rationale

The classical division of chemistry into five areas [organic chemistry (OC), inorganic chemistry (IC), analytical chemistry (AC), physical chemistry (PC), and biochemistry (BC)] dominates the structure of undergraduate chemistry curricula. Two main factors may account for the persistence of this structure: the organization of universities, in which departments and research groups typically reproduce these areas, and textbooks, usually introductory to the traditional areas (Goedhart, 2007). This classical division may have the undesirable consequence of creating excessively fragmented views of chemical knowledge or an excessive specialization among students. Such results oppose to the conception of how chemical education is supposed to be. Thus, to face the real challenges of current chemists' activities, it is necessary to develop an encompassing and integrated view of chemical knowledge. Such necessity is shared by many areas of knowledge, being a concern for many educators nowadays. According to Zabala:

“... it can be concluded that contents organization should allow the study of a reality which is complex, and to learn it is necessary to establish that maximum possible relations between the different contents which are learned, to improve its explaining capacity.” (Zabala, 2002, p. 35.)

When dealing with the matter of overcoming the traditional areas of chemistry, Goedhardt (2007) suggested a way to accomplish that:

“My starting point is to make an inventory of the different contexts in which chemists are active. I identify three: Analysis, Synthesis, and Theory Development. These are useful for describing the major activities of chemists and simultaneously for designing a curriculum to train new chemists.” (Goedhart 2007, p. 972.)

Context areas allow analyzing how chemists' activities transcend the limits of traditional areas, and are described as:

“I consider the context Analysis broader than traditional analytical chemistry... I would extend analysis to the determination of structures at the semimicroscopic... and microscopic level... The Synthesis context area describes the knowledge and skills related to synthesizing products with specific properties... Theory Development is concerned with the construction and validation (generation, accommodation, etc.) of models and theories based on observed and measured properties of substances and reactions.” (Goedhart 2007, pp. 972 – 973.)

Methods

This study analyzes an activity aimed to promote students' reflection concerning their conceptions about the nature and the organization of chemistry. Third year undergraduate students at the University of São Paulo (USP), being 23 chemistry bachelor's majors and 27 chemistry student-teachers and environmental chemistry students took part in this study. These students produced 14 concept maps organizing chemistry and chemical knowledge in areas and sub-areas, which are analyzed in the present work. Analysis criteria focused on how the five traditional areas of chemistry (OC, IC, AC, PC and BC) are conceived and represented in each of the concept maps and how students established links and connections between these areas. Only the relations between concepts belonging to distinct areas were analyzed, that is, connections between concepts within the same area were not considered. The following sentence is an example of relation between concepts belonging to different areas: “intermolecular interactions are the basis for separation methods”, for the concept of “intermolecular interactions” is usually related to PC, and “separation methods” are related to AC. On the other hand, the relation: “structural inorganic chemistry includes the study of metals” was not considered, since both concepts traditionally belong to IC. So, it does not show integration across two distinct areas. To categorize the selected relations, “context areas” were used (Goedhart, 2007).

Results

The maps showed uneven levels of details and organization, and different conceptions about chemistry. The maps were analyzed according to the way the traditional areas were dealt with (Table 1).

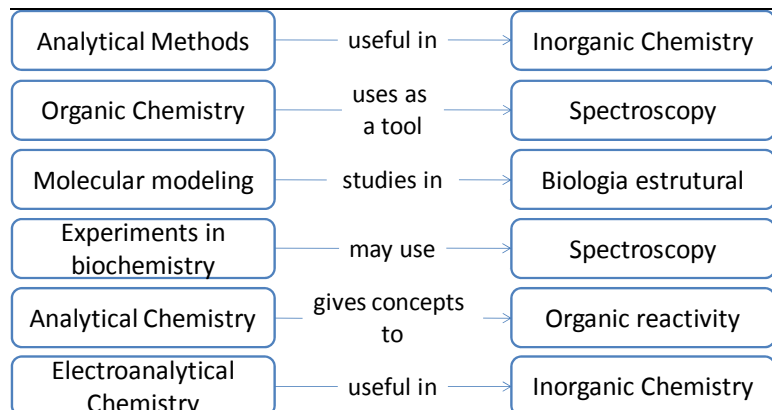
Table 1. Identification of the different areas of chemistry. “Other areas” include environmental chemistry, chemical engineering, chemical education, etc. – but not quantum chemistry, which is given more emphasis.

Areas	Other areas with the same <i>status</i> as the traditional ones	Number of maps
BC, AC, IC, OC, FQ	none	3
BC, AC, IC, OC, FQ	Quantum chemistry	2
BC, AC, IC, OC, FQ	Quantum chemistry + others	3
BC, AC, IC, OC, FQ	others	2
AC, IC, OC, FQ	none	1
IC, OC, FQ	others	1
undefined		2

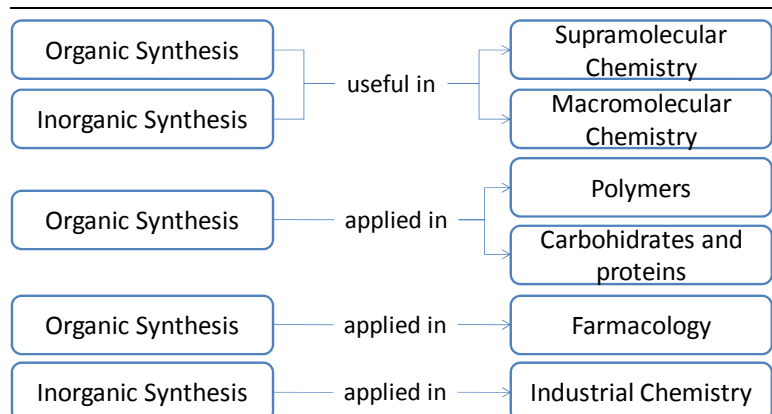
The emerging organization of the majority of the maps immediately suggests a structure built around the five traditional areas, as exemplified in Figure 1. Some of the traditional areas were absent in some of the maps, while in some maps other areas were added with a similar status.

Table 2. Selected examples and total number of connections (N) categorized according to context areas identified in 14 maps.

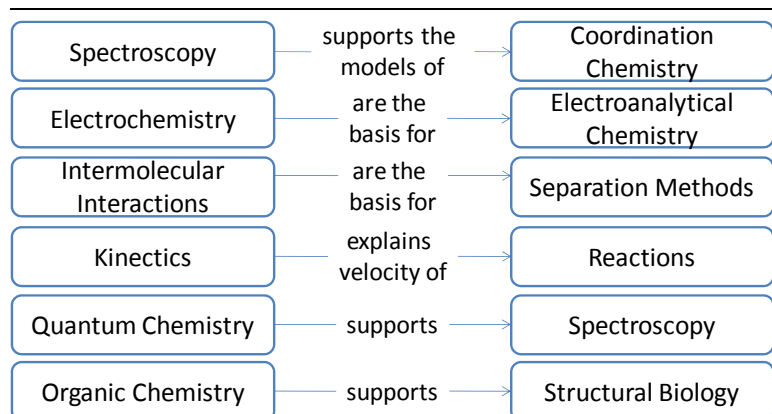
Analysis (N = 29)



Synthesis (N = 13)



Theory Development (N = 40)



Conclusions and Implications

The use of concept maps was a useful strategy to promote students reflection about their conceptions of chemistry as a science, its nature and organization. Results show that the understanding of students regarding to such aspects is uneven. On the one hand, a significant number of students were capable of elaborating rich maps, expressing good connections between many sub-areas and areas. The use of Goedhart's context areas as an analysis tool showed the prevalence of "Theory Development", suggesting that many students identify theoretical foundations that are subjacent to the different areas of chemistry – an important aspect towards the building of an encompassing and integrated view of this science. On the other hand, an also significant number of students had problems to present their view about chemistry, resulting in maps with few connections between areas. These students were not able to overcome the traditional division of chemistry in five areas, and reproduced the disciplinary structure of their courses. Thus, curriculum seems to be the major influence upon the students' conceptions about the structure of chemical knowledge. Results suggest that the challenge of developing an integrative view comprising the complexity of chemistry among students shall be considered along the entire undergraduate course.

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(Fapesp, CNPq, Capes)

**DOES THE TERM DYNAMOMETER
REFLECT ITS LINGUISTIC MEANING?
WHAT SHOULD BE CALLED:
FORCEMETER, WATTMOMETER, JOULEMOMETER...? WHY?**

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Abstract

In this work we are exposed to some reflections about logic and phenomenological contradictions that the model used to interpret the interactions in mechanical equilibrium presents. These reflections are accomplished on the dynamometer, since the interpretation of the mechanical equilibrium that takes place in it, upon applying the action and reaction model, presents linguistic and content problems.

Introduction

To everyone that may have a minimal knowledge of Physics, the term dynamometer is indissolubly and univocally associated with an apparatus that serves to measure force. Normally this spring is covered by two fixed cylindrical sections each one to an extreme, that slide within each other, with the internal section carrying the scale. This scale tends to be graduated in force units, normally pondios or newtons. The foregoing is dogmatically assumed in such form that anyone who reflects doubts about the type of equilibrium that takes place in the dynamometer and its fundamental theory can be considered, by the majority, an absurdity.

Exposition of the problem

Historically force has been a global concept and, consequently, ambiguous. From the writing of the Physics of Aristotle (1995) it is deduced that for him: a) force is not a property of the thing (body), it is something shared with the medium (air or water) in the one which has displaced the moved thing (interaction idea) and, b) force is the impetus of the movement that displaces the thing until it is exhausted (idea of systemic magnitude) that it could be quantity of movement or energy, or both. When Newton is challenged with the problem of the movement it is clear that there is a magnitude of the system which designates quantity of movement. But, the word force continues globally with the rest of the dynamic magnitude (energy, dynamic force, momentum of force, linear impulse, etc.), it included the mass (Truesdell, 1975).

Today, in the text books force is defined as:

Force is that which changes a body's state of rest or uniform motion in a straight line (Abbot, 1986, p.13).

A convenient mathematical notion to describe the momentum change of a particle due to its interactions with others ($\mathbf{F} = d\mathbf{p}/dt$) (Alonso & Finn, 1974, pp. 163-166).

4 That it changes its speed over time (Tipler, 1978, p. 93)...Upon the advancement of the phenomenological, the same author writes: force can be determined from potential energy. Force and potential energy in a unidirectional movement are related by $dU = -F_x dx$. Dividing by dx , results in: $F_x = -dU/dx$. Force is, therefore, the negative derivative of U with respect to x (Tipler, 1978, p. 236).

Concerning the adjectives that are attached to force are several and numerous, Alonso & Finn use the terms: *axial, central, centripetal, transverse, concurrent, conservative, coplanar, frictional, external, inertial, internal, nonconservative, normal, relativistic, tangential and transformational forces of Lorentz.*

The reason for the diversity of meanings for force throughout the history of Physics, in the social context and even in the current Physics, must be the fact that they have not sufficiently explicated the differences between the magnitude that characterizes the system (*linear momentum, angular momentum and dynamic energy*) and that which characterizes the dynamic interaction (*dynamics force, momentum of the dynamic force, dynamic power, linear impulse, angular impulse and dynamic work*).

This global character of the word force endures still. Thus, when the dynamometer is used to weigh, it is accepted that an equilibrium is produced between the “weight force” and the “reaction force of the spring”. This interpretation, assumed by the majority, allows certain critique. For example:

a) If force is defined as the infinitesimal temporary variation of the linear momentum, there remains no doubt that force should not exist once the equilibrium is established between the spring and the hung object (the elastic action of the spring and the gravitational interaction).

b) To admit that there exists an equilibrium among forces in the dynamometer is due, with great probability, to the fact that gravity is modeled as a force field. But where are the forces when there is no mass in the gravity field? Why is it modeled as a force field when what exists is a potential field and a gradient field of potential?

If it is admitted that in all space affected by gravitation there is a potential field, the equilibrium that is established on the hung object of the dynamometer is not between forces, but among potential energies (on one side potential energy, mPt , of the mass, m , located at a point in space affected by the gravitation whose potential value is Pt , and the other, elastic potential energy $[k(x)^2/2]$ of the spring with constant elastic, k , that it has been stretched x).

A possible solution

If we intend to use a universal scientific language for Physics, force must have a univocal meaning, equal to all the phenomenology and able to explain any physical situation. If force is defined as the temporary infinitesimal variation of the linear momentum, the force concept is limited to the fact that it exists as translated movement. This given definition will not be useful for other phenomenological physics, including the case of rotational movement, because the rotational system possesses angular momentum or kinetic momentum but not linear momentum.

However, the word *force* has universal character (encompassing all the phenomenology) within Physics if it is defined as *the positional infinitesimal variation of energy*. The modulus of force is the positional infinitesimal variation of energy and its direction is a function of the infinitesimal variation in the direction of the position.

This definition of force demands that a corresponding force for each type of energy, and within energies associated with movement, be established, subscribing to distinguish between the definition which derives from the translation energy (*dynamics force*) and the one which derives from the energy due to rotation (*kinetic force*). The adjectives perhaps will not be appropriate, but here we abide by the fact that translation dynamics has linear momentum and the angular or kinetic momentum is related to rotational energy.

Conclusions

The term dynamometer can not be assumed, since it can not be considered a device that measures movement: measure (meter) of the movement (dynamo) (Figure 1).

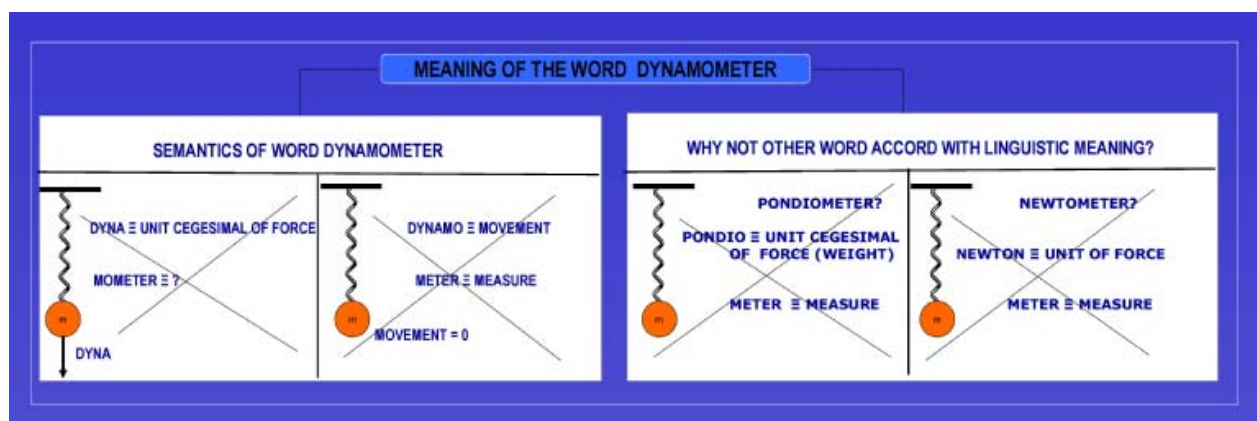


Figure 1. Meaning of the word Dynamometer.

The supposition of the word dynamometer has its origin in the designated force unit system that will be used, CGS system (cm, g, s), its content will be the “measurement of dynes”, and if it is in the International System (m, kg, s), “measurement of newtons”.

If the definition of force is accepted as the positional infinitesimal variation of energy, we have provided reasons in favor and we do not find, up to now, anything to contradict that in the “dynamometer” an equilibrium is established among gravitational potential energy of the body and elastic potential energy of the spring. Consequently, the dynamometer would have to be called a “joulemometer”, since it is measuring energies in equilibrium (Figure 2).

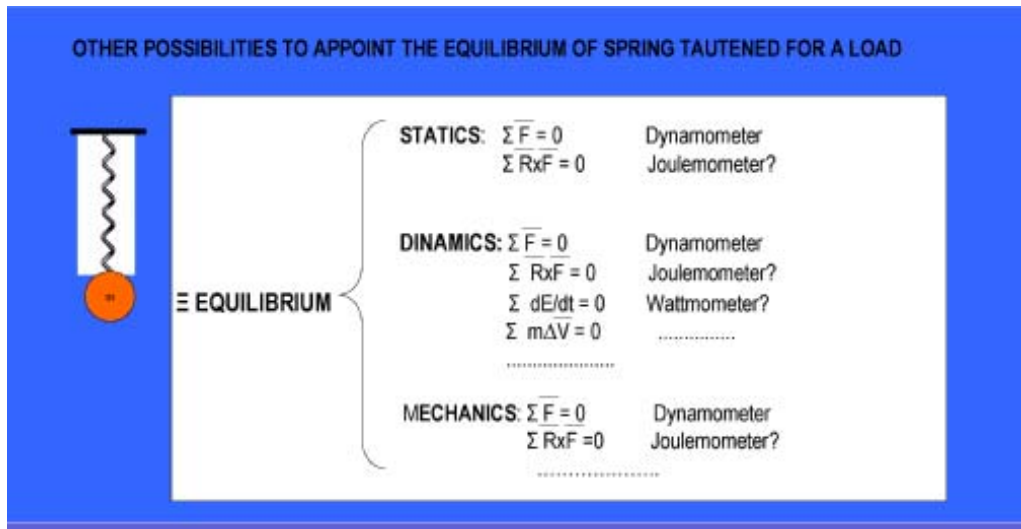


Figure 2. Other possibilities to appoint the equilibrium of spring tautened for a load.

Perhaps the device used to measure potential energies in equilibrium on physical systems does not have to be designated a Joulemometer. Nevertheless, it has been already noted that we are still waiting to establish logical procedures to designate magnitude and standardize physical instruments, but probably the unit designations will endure (Figure 3).

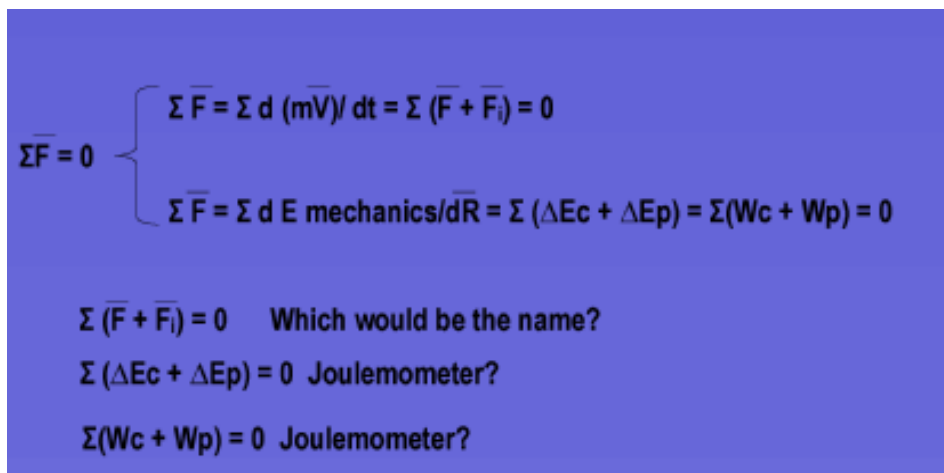


Figure 3. Which would be the name?

The word dynamometer is typical of words that are imposed through habit from the early contacts with the official Physics, never submitted to scrutiny nor criticized. In fact, to question results is difficult and its resistance to disappear endures with time.

The fact that Force is not defined in a universal language has important implications in:

- a) The science of Physics, because of its preexisting theories, for the most part, from the combination of fundamental magnitude that is integrated in the Technical-Terrestrial system (length, time, force, temperature and electrical intensity) and in the appropriateness to the present understanding (length, time, mass, temperature and

current intensity) from the International Committee on Weights and Measures, never received structural modifications.

b) The teaching of Physics intends to give force a univocal and universal character, but results are that its content are adapted according to the context of each phenomenology, furthermore, from the particular model that each phenomenology is interpreted. Thus, it is easy to observe, as we have seen before, the different adjectives that are added today to force. This situation makes teaching the concept of force complex, but it is even more difficult to learn the concept.

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UNIVERSITY STUDENTS' EPISTEMOLOGICAL BELIEFS ON NATURAL AND SOCIAL SCIENCES

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Abstract

The present research has used a case study approach involving interviews to investigate the epistemological beliefs of two undergraduate students from different courses (Physics and Physical Education) of a public Brazilian University. Students' discourse was analyzed in terms of the voice or perspective expressed in each utterance and the elements that could indicate epistemological beliefs and adhesion to social languages. The analysis showed that natural/biomedical sciences are epistemologically distinct from social sciences in students' discourse. The integration of the social languages representative of natural/biomedical and of social sciences seems to be favored in the Physical Education Course, which present a hybrid curriculum, but not stimulated in the Physics Course. Strategies that could help students to become aware of epistemological beliefs in order to favor the integration of natural and social sciences are recommended mainly in the courses that aim predominantly at technical formation in natural sciences.

Background

Inside such social space as the University, the subjects (both students and teachers) do not act as they were aware and conscious actors who obey some reasons with full knowledge of a cause, but act as being based on conceptions and practices that are shared between social groups. Therefore, even when they do not have any formal contact with philosophy of science as a discipline, university students build their vision of science in a tacit way, based upon the curriculum and on teachers' discourse.

Several ideological elements that permeate science education either in the secondary or in the University level take students away from social reality. Snow (1993) used the expression "two cultures" for pointing out differences amid the scientific culture and the humanistic culture, acknowledging that humanists do not know basic scientific concepts and scientists despise the psychological, sociological and ethics variables of scientific production. This break-up was considered by the author as "a serious danger for our creative and intellectual life, and, most of all, for our quotidian life, since highest level educated people do not manage to communicate in the area of your main intellectual interests" (p. 83).

When it comes to natural sciences courses, the curricular emphasis stresses the acquisition of abstract contents, which contributes to a limitation over the science education confronted to students' quotidian. There is also a so called asymmetry between types of knowledge, according to which the abstract learning is considered superior or even 'nobler', rather than the practical learning (Walkerline, apud Lemke, 2006). These are some of the aspects that can mold the vision of students over sciences, heading to the prioritization of an acquisition of technical concepts in a detriment of the critical vision of social reality issues.

Arroyo (1988) had also considered the separation between natural and human sciences when he attributed this disagreement as one of the consequences of the educational policies within Brazilian high school system in the 70's. He alerted to the fact that the students would develop sheer technical, formal, poor ways of thinking since they

would be kept away of a global formation that could promote a proper understanding of the complexity of social, political and cultural relations. This isolation among objects of knowledge has the “atomism” as a consequence, a concept related to a metaphysical comprehension of independent individuals within society, which is productive inside the west-based sociocultural environments.

Lemke (2006) points out that the aim of scientific education can not be merely technical, limited to producing “capacitated workers and consumers who have been educated to a global economy” (p.6), but should also remove science from the academic isolation, expand the universe of the learning process of the students in the classrooms, laboratories and virtual environments up to spots of community activities. The author also highlights that the learning process occurs through many ways, especially through language, as the semiotic systems are those which allow meanings of different modalities to be integrated, despite their origin – either written, pictured, spoken or observed.

We assume the hypothesis that this dichotomy converts the student of natural or biomedical sciences into a victim as, giving priority to the technical forms of thinking limits his general formation to understand the complex social, historic and political issues of our societies. Supposing the integration between natural and social/human sciences can be a necessary way to find solutions to socio-scientific problems faced by humanity today, it becomes relevant to understand how epistemological beliefs related to this dichotomy are discursively constructed in different University contexts.

Theoretical Framework

Sociocultural perspectives provide conceptual instruments to make sense of the ways discursive interactions shape social and cultural aspects of different social contexts. The concepts of discursive genre, voice and social language, from Bakhtin’s linguistics are very helpful in this sense. The election of a discursive genre is determined by the specific nature of a given sphere of verbal communication, by thematic considerations, by the concrete situation and by the personal composition of the utterance (Bakhtin, 2003). The notion of voice is related to the perspective of the speaker, his intellectual horizon, his intention and his worldview (Wertsch, 1993).

Regarding the speaker’s wider social horizon, his discourse is always constituted from a social language, i.e. “the peculiar discourse of a specific extract of society into a given social system and a given moment” (Holquist and Emerson apud Wertsch, 1993). Whatever be the principles that make them unique languages, the plan that unifies them is that they are points of view about the world, ways of conceptualizing the world in words, each one characterized by their own objects, meanings and values. As a result of this process, there are no neutral words in the sense that they always belong to someone.

However, not every word is submitted to the appropriation and assimilation within a new context; words can resist and force its coexistence inside people’s consciences, creating different and rather contradictory languages. In many social environments, one most appropriate language is then selected for one determinate issue. This process, which is initially unconscious but can become conscious whenever the individual notices contradictions between languages and world conceptions, is a part of any pedagogical phenomenon and, therefore, rather common within educational practices.

The Bakhtinian concepts can put light on the educational processes that configure the formation of an individual in the university environment which is still characterized by the “knowledge transmission epistemology” (Alarcão, 2001) and technical rationality. In this model, “knowledge should be treated as if it existed in a one-way route, with an unquestionable exact answer” (Camargo and Nardi, 2005).

Thus, we use socio-cultural perspective in order to enlighten the comprehension over how university students build their visions of science based on the living of pedagogical practices and discursive interactions with other students and professors.

Purpose and Research Question

Supposing that epistemological beliefs are expressed by means of discursive genres and social languages, we intend to investigate epistemological beliefs in the discourse of students from different University courses. The following question guides the investigation: discursive genres of students from different University courses express different epistemological beliefs and social languages?

Rationale and Methods

This research can be characterized as a case study and has a public Brazilian University as scenario. A student (Student 1) from the final semester of the Physics Course (PC) and a student (Student 2) from the final semester of the Physical Education Course (PEC) were interviewed. The differences among the curriculum of these courses were taken as an indication of the social languages shared in each context. The PC presents strong emphasis in Physics content. The PEC comprises disciplines on biomedical and social sciences as it aims teachers' education.

The interviewer suggested some topics concerning the disciplines and the course as a whole on which the students should reflect and talk. The interviews have been recorded and transcribed. Students' discourse was analyzed in terms of the voice or perspective expressed in each utterance and the elements that could indicate epistemological beliefs and adherence to social languages.

Results

Student 1's Interview

Student 1 valued the amount of scientific information given at the PC compared to the Physics Teachers Education Course (PTEC) and exalted the professors by the great amount of content transmitted in their lectures. He also stated that he appreciated the relationships established between theory and practice in the laboratory classes, which aimed to "show that what we learned is true". This utterance showed his empiricist view of Physics and his belief in the verification of scientific theories as discovery of the truth.

His position in respect to the disciplines related to the human sciences and education has become clear when he compared the PC to PTEC and the value that each of these social groups attributed to the subjects: the "hard" subjects were appraised by the PC students and depreciated by the PTEC students, and vice-versa. Within this matter, it is possible to notice traces of the separation between the cultures behind natural and human sciences revealed by Snow. He revealed that the disciplines of advanced Physics were valorized by the students from the PC and considered "boring" or "worthless" by the students from the PTEC. The discipline on History of Science was considered interesting but not necessary to the physicist formation, as it would actually take place within the specific disciplines.

The disciplines related to Education (obligatory for the PTEC) were considered of little relevance and educational researches were seen as irrelevant and distant from teachers' reality. The student mentioned the abstraction of human sciences (or their distance to concrete reality) as an argument to criticize them, regardless of the abstract character of the natural sciences.

When asked about his educational experience, Student 1 has emphasized individual aspects related to his personal efforts. Statements as "difficulty", "sacrifice", "challenges that I am becoming able to overcome" have appeared in different moments of the interview. He has also attributed the criticism students tend to make against the university course and the fails experimented by many students as an individual issue or sheer lack of dedication from the students - instead of blaming the course.

The student has magnified the “purely academic” aspect as what would define the quality of a course. However, in other moments, he compares this course to his first experience in another University, mentioning the differences of quality, especially when it comes to matters of organization and infrastructure of laboratories. In this judgement, technical rationality was noticeable meaning quality of teaching, when he emphasizes both material and organizational matters of the course and considers these aspects as “academic quality”.

Student 2's Interview

Student 2 valued the amount of information transmitted in the course as well as Student 1. She informed that, at first, she intended to work in sportive training but the contact with the pedagogical disciplines widened her horizon making her consider the pedagogical knowledge necessary to act even outside the educational setting.

The student has highlighted the criticism related to the disciplines that focus human sciences, due to the fact that many subjects have been ministered by teachers who have temporary contract with the University, which has damaged the “quality of teaching”. This particular criticism made evident how much she valued the quality of teaching and the relationship between teachers and students, which talk about both the contents dominated by the teachers, their motivation, the physical and structural conditions for a class to be held up and the students' effort to learn. Examples that related pedagogical practice to the efficiency of a course were abundant in her discourse, and, in certain level, to the technical rationality, especially within the perspective of the technical knowledge. But Student 2's discourse is also permeated of particular human aspects, such as the relationship between teachers and students and the relationship among college students.

The discursive genre elected by Student 2 denoted epistemological beliefs when she agreed that the lectures related to biomedical sciences (“an exact knowledge”), were expositive whereas in pedagogical disciplines the debates were frequent, although they were not always constructive.

When commenting the disciplines that she enjoyed the most in the course, the student seemed contradictory when it comes to the importance of the teacher. On one side, she has made clear that disliking a teacher and disliking a subject are completely different things, which makes the relation between the student and the subject something a lot more personal rather than something that in fact relies on pedagogical practices. On the other hand, she has combined the subjects she liked most to the dynamics of a teacher who was able to “keep the students interested”.

The personal effort emerged as a plausible explanation to achieve success as a student, just as for Student 1. In different moments of the interview, Student 2 says that the personal effort of one student can change the performance of a teacher which is considered “weak” or “uninterested”, just like interested teachers can “motivate lazy students”. Thus, she reduced all kinds of variables involved in the educational process to the motivational factor.

Conclusions and Implications

Natural/biomedical sciences are epistemologically distinct from social sciences in students' discourse: in Student 2's discourse, biomedical sciences are exact and unquestionable while the disciplines related to social sciences can be debated and collectively constructed. Student 1's discourse made clear the empiricist nature of Physics and the precariousness of social sciences.

Both students valorized the technical knowledge derived from the natural or biomedical sciences present in the curriculum. However, the students' voices were axiologically different when they referred to social sciences. The discipline on History of Science was considered by Student 1 as unimportant for his scientific formation; pedagogical disciplines and educational researches are not relevant for him. His discursive genre expresses the social language that gives privilege only to the content of natural sciences and no value to human or social sciences.

Student 2, alternatively, acknowledged that her knowledge basis amplified when she had contact with the social sciences. Besides, she valorized the teachers' pedagogical background.

Considering that Student 2 also valorized the biomedical content of the course, we can conclude that her discursive genre integrated the social language that values the biomedical sciences and the one that values the social sciences, probably shared by the social groups in the PEC.

The integration of social languages representative of natural/biomedical and social sciences seems to be favored in the PEC, which present a hybrid curriculum, and not stimulated in the PC. Assuming that students' voices are constructed in the interaction with social languages that are peculiar to different University contexts, the findings indicate that is necessary to implement strategies that could help students to become aware of epistemological beliefs and favor the integration of natural and social sciences, mainly in the courses that aim predominantly at technical formation in natural sciences. This initiative could also promote a more humanistic approach to socio-scientific problems that the whole society must take over nowadays.

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WHICH DEFINITION(S) OF WEIGHT DO WE TEACH? WHICH ONE IS CORRECT?

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Abstract

The purpose of this study is to classify different definitions of 'weight' concept by analyzing general physics books commonly used at the universities or colleges. 25 general physics books and seven physics dictionaries selected by online search at Middle East Technical University Library were investigated by content analysis method. Although it may contain little differences, the definitions of 'weight' can be classified into three groups. The books in the first group make the definition, with similar words, as 'the gravitational force acting on the object due to Earth', while the ones in the second group define 'weight' as 'the gravitational force acting on the object'. In the last group, 'weight' is defined as 'the force it exerts against a supporting floor or a weighing scale'. Consistent with the previous studies, many of the books prefer to define 'weight' as gravitational force. This study shows that the inconsistency in defining weight still exists in general physics books. Thus, a consensus should be provided to minimize the misunderstandings about one of the most fundamental concepts in physics, 'weight'.

Introduction

In recent years, concepts and conceptual understanding have been getting increasing attention. However, defining concepts properly and correctly is generally not an easy task. The difficulty of defining a concept sometimes results from the abstract nature of the concepts. For example, the reason for trouble in defining electricity is the fact that it is a quite abstract concept despite its concrete effects. In some cases, on the other hand, attribution of more than a single meaning on the same concept results in this type of confusion in understanding of concepts. The inconsistency of defining the concepts makes the understanding of related topics and understanding of the concept itself difficult for students.

The definition of weight, one of the most fundamental concepts in physics education, has been discussed in the literature for a long time (Sears, 1963; Iona, 1975, 1976, 1988; Morrison 1999; Bishop 1999; Galili, 1993, 2001). The debate has important potential implications because any change about how to define weight might force physics educators to revise some other concepts in physics curriculum (Galili, 2001). Weightlessness is an example of the concepts inherently depending on the concept of weight.

The purpose of this study is to classify different definitions of 'weight' concept by analyzing general physics books commonly used at the universities or colleges and to point out the inconsistency in defining weight.

Rationale

It is evident from the literature that there is a chaos in the definition of weight. Sears (1963) emphasizes the importance of defining weight and weightlessness correctly and proposes the definition of ‘the resultant gravitational force exerted on an object by all other bodies’ as the best to use in a physics course. He also indicates that ‘weightlessness does not mean that gravitational force is zero’.

Morrison (1999) examines some physics books and concludes that the most common definition of weight is ‘the force of gravity on the object produced by the nearest astronomical body’. However, he also draws attention to the existence of different definitions of weight in the commonly used general physics books like ‘the force exerted by the earth on an object’ or ‘the downward force experienced by an object a result of earth-object gravitational interaction’ etc... He emphasizes: ‘the physics-teaching community should address the issue and agree on common definitions’.

Bishop (1999) points out the inconsistency that Morrison stated and suggested the operational definition of weight, which is ‘what bathroom scales read’ or ‘the force required to support a body’.

Furthermore, Galili (2001) indicates the existing dichotomy regarding the definition of weight. He states that weight, force and mass are among most fundamental physics notions which affect general physics knowledge. He compares weight and gravitational force in historical and educational perspective and suggests a conceptual distinction between them and he strongly advises to use the operational definition of weight instead of gravitational force. In addition, Galili (1995) claims that understanding this concept is highly influenced by the confusion between weight and gravitational force, and Galili and Bar (1997) argue that there is a similarity between mental image of weight spontaneously constructed by children and the operational definition of weight.

Unfortunately, even after a long discussion in the literature, the inconsistency in defining weight still exists in physics education. This study aims to examine the definitions of weight and explanations for some weight related concepts like weightlessness and apparent weight in widely used physics books besides classifying different definitions of weight in these books.

Methods

25 general physics books and seven physics dictionaries, totally 32 books at METU Library were selected from the books reached by electronic search. By means of content analysis method, all the books were examined to find out which definitions of weight are included, and whether the inconsistency in defining weight still exists. Three criteria were set for inclusion of the general physics books. Firstly, it is aimed to get diversity in publication date and the authors. Thus, the books of different authors and from different publication date were decided to include the study. For the books having many editions, more than one edition was investigated.

Beside the definitions of weight, the explanations for weightlessness in the books were also recorded. Different definitions of weight were grouped into three categories. The books not having a consistent definition of weight, that is, the ones including definitions from different categories were included in the category of definition that was the most emphasized in the book.

Results

Different definitions in the books can be grouped into three categories with little discrepancies.

Definition 1: Weight is the gravitational force exerted on an object by the Earth.

Definition 2: Weight is the gravitational force acting on an object.

Definition 3: Weight of an object is the force it exerts against a supporting floor or a weighing scale.

In the first two categories weight is defined as gravitational force. However, the third category includes the operational definition of weight. As consistent with the previous studies, it is observed that in most of the books examined in this study (87.5%), weight is defined as either gravitational force exerted by the Earth or gravitational force (definition 1 or definition 2). Figure 1 illustrates the number books each category of weight definition includes.

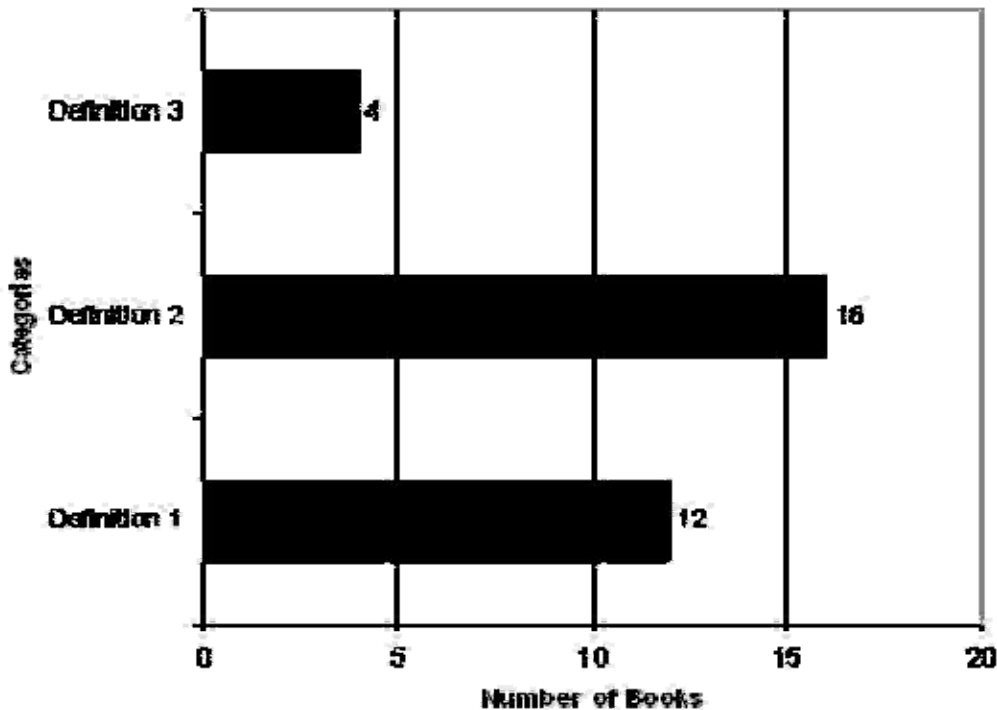


Figure 1. Number of books in each category of weight definition

Examples for Definition 1

Serway (1992) states that ‘the weight of a body can be defined as the force the earth exerts on the body’ (p. 104). Thus, ‘the weight of a body is equal to the product of its mass and the acceleration of gravity or $W=mg$ ’ (p.116). It is also indicated that ‘ $W=N=mg$ (when $a=0$)’ (p. 105).

Serway (1996) also indicates ‘when the elevator is accelerating, the spring scale reads the apparent weight’ (p.123).

Serway and Vuille (2007, p.66) and Faughn, Serway, Vuille, and Bennet (2006, p.88) define weight as ‘...the magnitude of the gravitational force acting on an object of mass, m near the Earth’s surface’.

Arons (1997) affirms that ‘the weight of an object is the gravitational force exerted by the earth on the object’ (p.66). He also points out ‘some teachers advocate defining weight as the number measured on the balance or scale, i.e., the force exerted by the object on the measuring device rather than in the simpler and more direct manner recommended above’ (p.67).

Furthermore, Young and Freedman (2008) state that ‘The gravitational force that the earth exerts on your body is called your weight’ (p.108) and also define the concept of apparent weight indicating ‘The scale reading is called apparent weight’ (p. 145).

Examples for Definition 2

Serway and Beichner (2000) clarify that ‘the weight of an object being defined as the magnitude of gravitational force is mg . $W=mg$ ’ (p.119). Serway and Faughn (2002) define weight as ‘the magnitude of the force of gravity acting on the object (scalar quantity)’ (p.141). Similarly, Jewett and Serway (2006) indicate that ‘weight is the magnitude of the gravitational force’ (p.103).

Cummings, Laws, Redish, and Cooney (2004) assert that ‘the magnitude of the gravitational force is commonly referred to as weight’ (p. 74). Zitzewitz (2002) describes weight as ‘a long range force due to gravitational attraction between two objects, generally due to Earth and an object’ (p.123). He also indicates ‘the force exerted by the scale is called apparent weight...weightlessness does not mean your weight is zero..... means that your apparent weight is zero’ (p. 130).

Hewitt (1999) also defines weight as ‘the force of gravity on an object’ (p. 49). However, he also points out that ‘rather than define your weight as the force of gravity that acts you, it is more practical to define weight as the force you exert against a supporting floor (or weighing scales)’ (p. 187). Similarly, Hewitt (2002) states that ‘weight is the force of gravitational attraction upon a body’ (p.22). However, he also indicates that ‘loosely speaking, we can define the weight of the body as the force a body exerts against the floor- or the weighing scales. According to this definition, you are as heavy as you feel’ (p.111).

Examples for Definition 3

Orear (1967) emphasizes ‘weight of an object is the force of the object against the floor...A person is as heavy as he feels’ (p.82).

Halliday, Resnick, and Walker (2001) state that ‘the weight of a body is the magnitude of the net force required to prevent the body from falling freely, as measured by someone on the ground’ (p.80). They also draw attention that ‘If $a=0$ (assuming the ground is an inertial frame), the weight of the body is equal to the magnitude of the gravitational force on the body’ (p.81).

Hewitt (2006) proposes:

a broader definition of the weight of something is the force it exerts against a supporting floor or a weighing scale. According to this definition, you are as heavy as you feel....If the elevator is in free fall; your weight is zero (p. 167).

He also indicates ‘weightlessness means being without a support force as in free fall’ (p.179).

Conclusions and Implications

Defining weight as ‘the gravitational force acting on an object’ like in the second definition has two important weaknesses. Firstly, this definition includes no explanation about what weight of an object would be if the object was not on a big planet but, for example, it was between the Earth and the Moon. That is, this definition cannot provide us with an answer to the question ‘would the magnitude of my weight be zero if I was at the point that the Earth and the Moon attract me with the force of the same magnitude but in the reverse direction (of course, if we ignore the attraction of any other celestial body)? Even we assume that we are on the Earth and we ignore attraction results from any other celestial body, this definition tells us nothing about whether my weight is effected by the Earth’s rotation or not. The weight definition in the first category includes another problems besides the ones mentioned above for the second definition. If we define weight as the gravitational force due to Earth, is it possible to mention weight on the other planets?

Another problem arising from teaching definition 1 and 2 is that students may conclude that weightlessness means no gravitational force. For example, students think that astronauts floating in the shuttle experience no (or very weak) gravitational force because they seem like weightless (Galili, 1995).

The operational definition in the third category does not share the weaknesses of the first two definitions. Within operational definition, astronauts floating in the shuttle are really weightless and that does not mean there is no gravity because of the distinction of weight and gravitational force. However, it induces new difficulties. For example, whatever the reason is, if any contact or non-contact force exerts on our body, the operational definition infers that our weight will change. That is, I should conclude that my weight will increase if one of my friends puts his/her arm on my shoulder. Another difficulty is that operational definition gives the students no information about the essence of the concept, i.e. what actually weight is.

To sum up, this study clearly shows that the inconsistency in definition of weight still exists even in the general physics books. All point of views related to each definition have some weaknesses. However, the purpose of this study is not to argue the relative merits of the different definitions. The point is that the inconsistency in definitions of weight results in more problems than the ones any of the definitions may cause. Furthermore, the inconsistency in defining concepts is not limited to 'weight' but similar problems exist in the physics concepts of 'heat', 'thermal energy', 'light', and 'force'. Thus, the conflict in the books and physics education should be prevented by developing a consensus about which definition is more correct, proper, or useful. Otherwise, as Morrison (1999) says, 'public ignorance and misunderstanding of many common physical phenomena —e.g. "weightlessness" in orbit—is, in part, our own fault'.

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WHAT IS THE NORTH STAR OF TEACHERS? CURRICULUM OR NATIONAL EXAMS

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Abstract

Many countries developed their curricula on the basis contextual approach; such as, the Dutch PLON project in the Netherlands, Large Context Problem Approach in Canada, Applications-led approach in Scotland (UK), Event-centered learning in Brazil and the UK, Supported learning in Physics Project in UK, the VCE physics course in Australia, and finally the new context-based curriculum of Turkey. However, of course, curriculum design is not enough alone because teachers are responsible to put into practice the curriculum, their knowledge, beliefs and attitudes toward a new curriculum is very important. Therefore, the purpose of this study is to understand physics teachers' beliefs and implementations about the new physics curriculum in Turkey.

Introduction

In most countries, physics has been taught by giving core facts and laws of physics since 1960s. When doing this, physics classes present much chalk and talk, few demonstrations and almost no activities (Wilkinson, 1999). Such an instructional approach has yielded in some problems in physics teaching. For example, (1) curricula have become over-loaded (overload), (2) facts and laws are presented without giving any connection to other ones (isolated facts), (3) students can solve problems similar to the ones taught to them but they cannot use the concepts in those problems to other problems with a different situation (lack of transfer), (4) students cannot find out why they should learn the content courses offer (lack of relevance), (5) inadequate emphasis on the scientific literacy (Gilbert, 2006). At last, the notion “context” as a basis for curriculum development is hoped to overcome the aforementioned problems (Gilbert, 2006).

Rationale

In recent years, many countries developed their curricula on the basis contextual approach; such as, the Dutch PLON project in the Netherlands, Large Context Problem Approach in Canada, Applications-led approach in Scotland (UK), Event-centered learning in Brazil and the UK, Supported learning in Physics Project in UK, the VCE physics course in Australia, and finally the new context-based curriculum of Turkey (Wilkinson, 1999). However, of course, curriculum design is not enough alone because teachers are responsible to put into practice the curriculum, their knowledge, beliefs and attitudes toward a new curriculum is very important (Haney, Czerniak, & Lumpe, 1996). As a result, the purpose of this study is to understand physics teachers' beliefs and implementations about the new physics curriculum in Turkey.

Methods

The participants consist of ten physics teachers working at the high school. In Turkey, all the physics teachers have to use the new curriculum in physics classrooms at the first year of the high schools. Therefore, all the teachers are supposed to be currently implementing context-based approach at the 9th grades. The participants were selected through the snowball method. Snowball sampling obtains knowledge of potential cases from people, who know people who meet research interests (Glesne, 1999). Because of the sampling method, participants were identified by colleagues as innovative and well-known physics teachers currently working in high schools. They had taught physics at least for eight years in high schools.

All of the participants were interviewed individually. All interviews in Ankara were conducted face-to-face and intercity interviews were conducted through speaker phone. There were four key questions related to the general implementation of the new curriculum. The remainder of the interviews elaborated on points that had been raised in the conversation. The key questions were: (1) How did you get information about new curriculum? (2) Have you changed your pedagogical approach in the 9th grades? (3) What are some of the positive outcomes of implementation with context-based approach? (4) What are some of the constraints to implementation with context-based approach? All interviews were transcribed for analysis. The researchers coded the responses to search for common themes.

Results

In this study, three claims have been raised related to the implementation and they will each be presented in the form of assertion. The first one is that teachers do not have sufficient knowledge about how new physics curriculum can be implemented. The second one is that teachers believe a context-based approach to physics makes physics more relevant. Lastly, the third one is that teachers do not want to change their instructional approach because of the national exam.

All participants asserted that they know the new physics curriculum. However, during the interviews it was revealed that their knowledge about how new physics curriculum can be implemented is limited. Although they said that they had read the new physics curriculum on the internet, they had only surface knowledge such as topics on the 9th grade. This kind of knowledge possibly can be acquired from student textbooks. Participants did not know main characteristics of new physics curriculum like holistic approach. They described context-based approach as if it is only giving real life or technological examples.

Participants expressed the view that using real life contexts in the lessons makes physics more relevant to the students' life. This is not surprising since the research on context-based teaching in the Australia and United Kingdom have found similar results. For example, Hart, Fry and Vignouli (2002) asserted that many students saw the relevance of physics to real life and increased motivation with the context-based approach.

Participants thought that there are many difficulties to implement new curriculum such as teacher competency, students' and parents' resistance to change, and limited lesson time. Most importantly, they do not want to change their pedagogical approach because of the national exam. Teachers' main concern is to prepare students to the national university entrance examination instead of deep understanding of physics concepts. National exams are like hidden curriculum for them, because their success is mostly measured by it.

Conclusions and Implications

The results show that teachers are unwilling to implement new physics curriculum even though they believe some aspects of it are useful for students. Implementing a new curriculum is not an easy task and requires enthusiastic teachers who are ready to change despite constraints to implementation. There is no reason to change their pedagogy if teachers do not want to change it. The results of this study indicate that some adjustments are needed: firstly, the structure of the national exams should be changed and secondly, more education about the new physics curriculum is needed for the teachers.

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CHEMICAL REPRESENTATIONS: BRIDGING SUBMICROSCOPIC AND SYMBOLIC DIMENSIONS OF CHEMICAL KNOWLEDGE IN LIGHT OF PEIRCE'S THEORY OF SIGN

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Abstract

The purpose of this study was to understand the meaning promotion in light of Peirce's theory of sign in a virtual learning environment where students could create and manipulate virtual molecular objects.

Introduction

Representation is an important subject in science education. Thinking chemical representations in macroscopic, submicroscopic symbolic levels, the last one offers more obstacles for understanding in a particulate level, and important properties are better presented by means of computational resources. In this work we present a tool to help high-school students better understand some chemical representations using a virtual learning environment to improve the contact of students with chemical representations in educational activities, and discuss the results in light of Peirce's theory of sign.

Rationale

Representations are intrinsic elements in chemical knowledge because of its nanoscopic treatment of matter. They present information about macroscopic, submicroscopic and symbolic dimensions of the chemical interpretation of nature. Some representations (e.g. structural formulas) bring both arbitrary and isomorphic information, like element symbols and atomicity, and may be related to logic-mathematical operations or simply point to the aggregation state of a substance. In classroom activities the symbolic dimension of the chemical knowledge may be mistreated only as mathematic formulas, while the submicroscopic dimension is, many times, presented in a two-dimensional way. Thus, important information about the particulate nature of matter is missed, and students are unable to understand those representations as dynamic and interactive.

Despite the importance of correct use of chemical representations, students usually face problems when asked to operate with them in class activities. We then choose to base our study in a theory that explicitly handles representations and the way they reach their meaning. Peirce's semiotic theory proposes (Peirce 1981) that the relationship between signs and its objects let us classify signs according to their sign-vehicle function due to similarities (icon), existential facts (index) or conventions/laws (symbol). Each dimension of chemical interpretation of nature (macroscopic, submicroscopic and symbolic) has different kinds of representations, and they may vehicle iconic, indexical or symbolic meanings. Submicroscopic dimension of chemistry, which deals with particle

interaction and movement, may be better represented now as computational resources are getting more powerful and cheaper. This kind of representation may be classified as iconic when the target is to emphasize the dynamic and interactive nature of particles. Symbolic dimension of chemistry, which deals with representations by letters, number and chemical symbols, are used as a simpler representation and when logical/mathematical operations are necessary. This kind of representation has symbolic (law/convention) meaning when used to represent properties and physical greatnesses.

As some chemical representations have multiple meanings (e.g. structural formulas meaning the amount of atoms and three-dimension positioning), some of these meanings are not clear to students in only-speech classes, and it is necessary to emphasize these meanings in activities where it is possible that students manipulate molecular objects. Concrete molecular objects are useful to these activities, but some dynamic properties, like relative movement of atoms in a molecule, cannot be shown by these means. Computational representations offer the possibility to show students many aspects of the particulate nature of matter. We developed a virtual learning environment where it is possible for students to generate and manipulate three-dimensional molecular objects in a simplified way: using the condensed structural formula of a compound.

Methods

We developed a virtual hypertext learning environment for the student's activities. These activities included creating, visualizing and manipulating representations of both submicroscopic and symbolic levels of chemistry. For submicroscopic level representations we used Jmol Java® applet built-in in hypertext pages which allows the user to manipulate virtual molecular objects. The virtual learning environment included a tool named Construtor, developed by our group, which generates three-dimensional molecular objects from condensed structural formulas of organic compounds (e.g. CH₃CH₂CH₃). This tool was written in C language and runs in a GNU-Linux server, and the students accessed both hypertext pages and Construtor through internet. The virtual learning environment also included a multiple recording system where students' actions and the screen-in-use were synchronically recorded in digital format. The recording system was built-in in the computer used by the students as softwares running in background and a webcam.

A group of 38 high-school students performed the activities in a computer lab with access to the internet, and they worked in pairs for the proposed activities. A focus group was chosen to be filmed by the multiple recording system during the activities. After 2 sessions of 3 hours each in two different days the group finished the proposed activities and answered a questionnaire. We chose some parts of the recording in which we have observed some change in students' interest, and we have showed these clips individually to them. After watching themselves in a movie (a dual screen with their actions and the screen they were working) we interviewed them and asked if and why their interest had changed at that time. We used these movies to bring to their memories what was exactly happening that time. One of questions from the questionnaire, and part of the interview are analyzed below.

Results

In one of the questions we asked the students to vote about the ease or difficult when using the tool Construtor, where they had to type in a valid condensed structural formula to receive as answer from the server a tree-dimensional molecular object. They were asked to vote in a Likert scale where 1 meant very difficult and 5 meant very easy. Table 1 shows the result.

The categories "normal", "easy" and "very easy" together make 85,3% of the answers, which are the categories with bigger percentage of answers. Despite student's usual difficulties when dealing with the symbolic dimension of chemical interpretation of nature, the answers show that students didn't have much difficult to work with these formulas, on the contrary, they found it quite easy to deal with submicroscopic and symbolic representations at once. Peirce's sign theory helps understand why students face problems to understand particulate

properties from letter-and-number representations, but they do not face much problem when dynamic molecular objects are put together. According to his theory, iconic representations mean by similarity (visual or in properties) to its objects (target meaning). It is easier to students to understand stereo constraints in a molecule by observing and manipulating a molecular object with appearance of balls and sticks than drawing letters and number to them. Balls and sticks together forming a molecular model look more familiar to them than numbers and letters linked by traces.

Table 1. Student's percentage of answers when asked about difficulty or facility to using the tool Construtor, in which they faced both representations of submicroscopic and symbolic chemical dimensions.

%	Likert scale
2.9	1 – Very difficult
11.8	2 – Difficult
23.5	3 – Normal
47.1	4 – Easy
14.7	5 – Very easy

When interviewing one of the students, after showing him a video about his activities in the lab, we asked him why he got more interested when he first saw that the tool Constructor would return him a tree-dimensional molecular object, after typing a formula. Actually the video showed him and his partner laughing and clapping after the result. We quote his answer below:

“It is funny, ‘cause I look at this table, and I can't imagine all that little balls (ball and stick models, both concrete and virtual) in this table. This table is made from a lot of these little balls, these molecules. You look at it and you can't see atoms in stuffs, but then you see that stuffs... I know that stuffs are made from atoms, but I can't see atoms, so when guys can see it's cool, it's interesting”.

When students have no contact with representations of the submicroscopic dimension of chemistry, it is possible for them “to know” that things are made from atoms, and also “know” dynamic properties of molecules. But it is quite complicated to them “to imagine” these properties because there is nothing really alike in macroscopic world available in everyday life, and also because no one might ‘see’ atoms. Nowadays it is possible to show them these properties taking advantage of computational resources and the iconicity it is able to mimic.

Conclusions and Implications

Maybe one of the best situation to teach chemistry would be students writing and manipulating three-dimensional representations full time. As it is not possible because of the complexity of these representations, there is a symbolic dimension in chemistry to represent also the submicroscopic aspects. But these representations do not help students to imagine or understand important particle properties, and some might even believe that chemical symbols have just logical-mathematical purposes.

Table 1 shows that students do not found difficult to deal with symbolic and submicroscopic representations. As they generated these representations by typing in the corresponding formula and could easily manipulate the molecular objects, three-dimensionality and dynamic properties became more concrete to them, instead of just trying to imagine the corresponding submicroscopic world. Also the interview suggests that seeing and manipulating molecular objects along with the symbolic representations make it possible to students to bridge submicroscopic chemical world and its symbolic representations. It may be a way to broad students' conventional meaning of bi-dimensional representations, as they will face them more frequently than any other.

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PART 2
HISTORY, PHILOSOPHY, AND SOCIOLOGY OF SCIENCE

BIOLOGY PROFESSORS' AND TEACHERS' POSITIONS REGARDING BIOLOGICAL EVOLUTION AND EVOLUTION EDUCATION IN A MIDDLE EASTERN SOCIETY

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Abstract

This study investigated three questions: 1) What are secondary school biology teachers' and college biology professors' positions regarding the theory of evolution? 2) How do participants' religious beliefs relate to their positions about evolution? And 3) What are participants' positions regarding teaching of evolution? Participants were 20 secondary school biology teachers and 7 university biology professors. Seventy percent of the teachers and 60% of the professors were Muslim. Data came from semi-structured interviews with participants. Results showed that 9 (Christian or Muslim Druze) teachers accepted the theory, 5 (4 Muslim) rejected it because it contradicted religious beliefs, and 3 (Muslim) reinterpreted it because evolution did not include humans. Teachers who rejected or reinterpreted evolutionary theory said that it should not be taught (3), evolution and creationism should be given equal time (2), or students should be allowed to take their own stand. Two professors indicated that they taught evolution explicitly and 5 said that they integrated it in other biology content. One Muslim professor said that she stressed "the role of God in creation." It seems that years of studying and teaching biology has not had a transformative effect on how a number of teachers and professors think about evolution.

Introduction

Biological evolution is globally and overwhelmingly accepted by the scientific community as an "evidence-based fact" which scientific evidence has "never contradicted" as attested in an Inter-Academy statement adopted by the academies of science of over 67 countries including the developing world (InterAcademy Panel [IAP], 2006). In accord with most major scientific and science education associations, individual national academies signatory to the IAP statement have deemed evolution to be "the only explanation for the diversity of life on this planet that is acceptable to the scientific community" (Academy of Science of the Royal Society of Canada, 1985) and "the central unifying concept of biology" (National Academy of Sciences, 1999). Hence, evolution should be a central, and

noncontroversial, element of biology teaching and learning. However, the teaching of evolution continues to be socially controversial, primarily because of its perceived conflict with personal religious beliefs.

Although different Muslim and Christian religious sects have distinct, and often supportive, positions on evolution, it remains an apparent challenge to certain religious accounts of creation in both religions (Dagher & BouJaoude, 1997). According to Dagher and BouJaoude (1997), “the dominant Judeo-Christian account of the origins, based on the book of genesis in the Bible, states that God created the heavens and the earth and what is in between” (p. 430). A similar account is present in the Quran, the holy book of Muslims, which includes many verses about creation. Muslim intellectuals and educators tend to interpret these Quranic verses in diverse, often conflicting, ways (Asghar, Wiles, & Alters, 2007a; b). In his turn, Mayr (2000) believes that the theory of evolution was controversial since its formulation because it challenged a range of religious, ethical, and even scientific beliefs of the time. For example, the concepts that humans evolved from lower species, that ethical behavior is favored by natural selection to preserve the community, and that randomness rather than predictability may govern natural processes were unacceptable ideas at Darwin’s times. The social controversy over the theory of evolution and its teaching is likely to be carried to the classroom because students and teachers are influenced by their cultures and societies. Examples of such controversy are abundant in the USA where evolution education has become an important political issue (see Berkman, 2008). In addition, a recent essay appearing in the prestigious journal *Science* warns that evolution may be becoming increasingly controversial in Muslim societies where arguments against the theory are popularized in many books on the topic (Hameed, 2008).

Research in the USA has shown that significant numbers of college students reject evolution (Ingram & Nelson, 2006; McKeachie). Similarly, research in Lebanon has shown that, while most college biology students understand the principles of evolution, approximately 50% of them reject the theory. This rejection, however, is related to students’ religious affiliations as evidenced by the fact that 82% of Christian students accepted evolution and only 35% of Muslims did so (Dagher & BouJaoude, 1997). In another study with college biology students who completed a course on the theory of evolution, Hokayem and BouJaoude (2008) found that students’ positions ranged from complete acceptance to complete rejection of the theory. Furthermore, in a study conducted in Lebanon and Egypt, BouJaoude and Kamel (2009) found that secondary level students thought that evolution is both a fact and a theory and that it is a theory because it is not yet proven scientifically. Moreover, the study showed that a higher percentage of Lebanese Muslim students than Christian or Druze students thought that their religion teaches that the first life and humans on planet Earth were created by God, not gradually but suddenly in their present human form, accurate science includes religious explanations, evolution is best learned from the holy book of their religion, biology classes should include their religion’s explanations of human and animal history on Earth, God created human beings pretty much in their present form at one time within the last 10,000 years or so, and their religion influences how they think about evolution. Alternatively, results regarding Egyptian students’ conceptions of the relationship between science and religion showed that Muslim and Christian students had similar misconceptions about evolution except that a higher percentage of Muslim than Christian students thought that biology classes should include the religious explanation of human and animal history and that religion influences how they think about science.

Finally, in a series of recent studies conducted in different countries in Europe, Africa and the Middle East, Clément, Quessada, Laurent, and Carvalho (2008), found that biology teachers were more accepting of evolution than language or elementary school teachers, atheist and agnostic teachers accepted evolution more than Muslim and Christian teachers, and Christian teachers accepted evolution more than Muslim teachers. Importantly, they showed that there were differences within Christians; with Orthodox teachers - who came mainly from Romania or Cyprus - more opposed to evolution than catholic or protestant teachers. Moreover, they found that there was widespread rejection of evolution in countries with Muslim majorities. In their turn, Clément and Quessada (2008) showed that teachers who identified themselves as Christian in Northern European countries, such as France, Germany, and Finland were more accepting of evolution than Christians from other countries such as

Cyprus and Lebanon. Finally, Quessada, Munoz, and Clément (2007) found that irrespective of the level they taught or the country they came from, teachers with longer training were more accepting of evolution.

Purpose

Research has shown that many students reject evolution based on their religious beliefs. However, what is *not* known is how biology teachers and college professors in Islamic communities think about evolution and how their views influence their pedagogical decisions. Lebanon presents a good context to conduct such research because it is an Arab country in which almost 65% of the people are Muslims of the Sunni, Shiite, and Druze¹ traditions while the rest are largely Catholic or Orthodox Christians. Consequently, this study explored the following questions: (a) What are secondary school (Grade 9-12) biology teachers' and college biology professors' positions regarding the theory of evolution? (b) How do participants' religious affiliations relate to their positions about the theory of evolution? (c) What are participants' positions regarding evolution education?

Method

Context

Almost 60% of students in Lebanon attend private schools, often affiliated with Christian or Muslim institutions, many of which offer the national curriculum along with foreign curricula. Evolution was initially included in the country's science curriculum; yet, it was officially removed under pressure from the religious establishment. Schools offering foreign curricula have the freedom to teach evolution.

Participants

Participants were 20 secondary school biology teachers (80% females) and 7 university biology professors (25% females). All teachers held undergraduate degrees in biology, 40% had science teaching credentials, 20% completed or were pursuing master's degrees in science education, and 70% had more than 3 years of teaching experience. Seventy percent of the teachers were Muslim (5 Shiite, 5 Druze, 4 Sunni) while the rest were Christian (3 Catholic, 3 Orthodox). All professors had biology doctorates. Approximately 60% of the professors were Muslim (2 Sunni, 1 Shiite, 1 Druze), 2 were Christian, and 1 agnostic. The professors came from an American-style university in which the language of instruction is English and in which evolution is taught as an elective course.

Data Sources and Analysis

Data came from 25-30 minute, semi-structured interviews with the teachers and professors. Most participants consented to audiotaping the interviews. Interviews were later transcribed for analysis. Extensive notes were taken during the interviews with the five individuals who did not consent to audio recording. The codes developed by Dagher and BouJaoude (1997) were used to analyze data related to participants' positions about evolution and the relationship between these positions and religious beliefs (Table 1). No new categories emerged during data analysis which was conducted by three researchers who discussed and reached common understandings of the codes. Initially, one case was analyzed independently (inter-rater reliability was 70%) and the results and discrepancies were discussed between researchers to reach consensus. Consequently, the researchers analyzed the remaining interviews. The constant comparative method was used to refine and compare categories across cases. Participants' ideas regarding teaching of evolution were grouped under three major categories following a similar method: What is taught about evolution, how it is taught, and whether or not it should be taught.

¹ According to Makarem (1974), the Druzes belong to an esoteric Islamic sect based on a philosophical background that appeared at the beginning of the 11th century. It differs in many respects from traditional Islam and remains inaccessible to many of its adherent.

Results

The results are divided into two sections. In the first section we present university professors' and teachers' positions regarding the theory of evolution along with their objections to evolutionary ideas and how their religious affiliations relate to their positions about the theory of evolution. In the second section we present professors' and teachers' positions regarding evolution education.

Biology University Professors Positions Regarding Evolution

Data analysis using the codes presented in Table 1, shows that university professors either accepted (4 professors) or reinterpreted (3 professors) the theory of evolution. Specifically, professors who accepted the theory were either Shiite Muslims (one professor), Christian (two professors), or agnostic (1 professor) while the remaining three professors reinterpreted the theory (2 Sunni Muslims, 1 Druze). Below, we present selected excerpts from teachers' interviews to illustrate the positions presented in Table 2.

University professors who accepted the theory. Four of the seven professors accepted the theory of evolution. Their positions however are based on apparently different arguments. U3, a Christian, accepted evolution based on “scientific proof for the theory” and lack of these proofs in the Old Testament. U4, also a Christian, said that he did not believe in creation but that he believed in “a God that orchestrated evolutionary events”. U6 and U7 (agnostic and Shiite) seem to have based their acceptance of the theory on its strong explanatory power of biological phenomena.

Table 1. Codes used to analyze interview transcripts regarding beliefs about the theory of evolution and its relationship to religious beliefs

Position	Elaboration
Individuals who accepted evolutionary ideas using arguments from an evolution or reconciliation perspective.	<ul style="list-style-type: none"> • Evolution: This perspective endorses the scientific arguments for evolution based on scientific evidence. • Reconciliation: This perspective interprets evolution and creation in such a way that the new interpretation does not contradict the general assumptions of evolution or liberal accounts of creation.
Individuals who rejected evolutionary ideas presenting arguments from a creation or antievolutionary perspective.	<ul style="list-style-type: none"> • Creation: This perspective emphasizes the religious teachings about the existence of a Creator or the scriptural accounts of creation (typically they adopt a literal interpretation of the scripture), and rejects the theory of evolution because it is incompatible with the religious teachings. • Antievolution: This perspective rejects evolution on the basis that it is problematic from a scientific standpoint.
Individuals who reinterpreted the Theory arguing from a compromise perspective.	<ul style="list-style-type: none"> • Reinterpret: This position reflects selective interpretation of the theory of evolution in an effort to reduce its perceived conflict with religious beliefs. However, the theory becomes unacceptable from a scientific point of view
Individuals who were neutral espousing either a non-committed or a confused perspective	<ul style="list-style-type: none"> • Non-committed: This perspective reflects unwillingness to take a stand. • Confused: This position reflects the inability to take a stand.
Objections to the Theory of evolution	<ul style="list-style-type: none"> • Objections to evolutionary ideas are mainly represented in the “against evolution” and the “compromise” positions, but could be also found in responses that take the reconciliation position. Different types of objections to the theory could be classified along four themes: conceptual difficulties; alternative interpretations; nature of science (NOS); and nature of religion.

The following excerpt illustrates the positions of University professors who accepted the theory evolution.

- *First it [Evolution] puts explanation to biology, evolutionary biology helped a lot in understanding living things, and there's no doubt about this, for example you now this organism is related to this organism, you can do medicine out of this, I might be able to use a certain chemical that can control both organisms, in human society there might be the ethical point of view that I mentioned to explain why humans have to be nice to each other, not because God said love thy neighbors, no because there's a biological need to be together, humans have been together for a long time, humans didn't come together with Christ, or with Mohammad, not with any one, human societies have to stick together, there's a biological need to be in a society (U7, Shiite).*

Table 2. University professors' positions regarding evolution categorized by religious affiliation.

	Muslim			Christian	Agnostic	Total
	Shiite	Sunni	Druze			
Accept	1			2	1	4
Reinterpret		2	1			3

University professors who reinterpreted the theory. Three out of the seven professors seemed to interpret selectively the theory of evolution in an effort to reduce its perceived conflict with religious beliefs. Here again it is clear that there were at least two ways in which the professors reinterpreted the theory. The first two professors, both Sunni Muslims, were very clear in the rejection of the theory of evolution, and their belief in certain elements of the theory that did not seem to be in conflict with their religious beliefs. For example, both professors believed in the special creation of humans. The third professor seemed to be disentangling the issues of evolution from creation in an attempt to reduce the conflict between the theory and religious beliefs. The following excerpt illustrates the positions of University professors who reinterpreted the theory evolution.

- *God has created the world in 6 days; 1 day does not mean 24 hours, they are 6 periods. So they could be the transition periods through which the evolution process has gone through ... This evolution is taking place under the eye of the God. I find no conflict (between religion and evolution). Natural selection? Definitely we should believe in that... the survival of the fittest? For sure... there is no conflict with believing that there is a creator, there are no conflicts at all... Now when it comes to the origin of the world, yeah, for me this is not acceptable, not because I am a committed Muslim, but because I find it illogical...if you review the laws of thermodynamics, all of them work against the theory of evolution, the world goes toward maximum disorder, Entropy...I think that if you are a good biologist, you would definitely be a good...a believer in a Creator...because this order cannot come from nothing. This creation may have taken six steps, but it is when you reach this form that you have become a human being. That could be a possibility. After all, how can we know that all these are correct? After all they might be speculations...But all the intelligence was there, the abilities were there. God says "We have indeed created man in the best of mold" (Surah At-Tin, Ayah 4) this is true for me as a believer (U1 [University Professor 1], Sunni Muslim).*

The results above do not present a clear pattern regarding the relationship between university professors' religious affiliation and their positions regarding the theory of evolution. As Table 2 shows, the only possible pattern – which is very tenuous because of the small number of participants – is that the three professors who identified themselves as Christian or agnostic were supporters of evolution. The four other professors included one Shiite Muslim who accepted the theory of evolution, two Sunni Muslim professors who and one Druze professor who reinterpreted the theory.

University Professors' Objection to the Theory of Evolution

Two of the university professors objected to the theory of evolution based on religious beliefs and thus reinterpreted certain elements of the theory to reduce the conflict with their religious beliefs. However, one of these professors seems to suggest that the theory is not conceptually coherent because it is "Illogical" and does not seem to account for the complexity in living organisms.

Biology Teachers' Positions Regarding Evolution

Data analysis using the codes (Table 1) shows that teachers were divided almost equally between those who accepted the theory of evolution (9 teachers) and others (11 teachers) who rejected the theory, reinterpreted the theory, were non-committed, or were confused. Specifically, teachers who accepted the theory were either Druze or Christian (5 Druze and 4 Christian), while the remaining 11 teachers either rejected the theory (4 Shiite or Sunni Muslim and 1 Christian), reinterpreted the theory (3 Shiite or Sunni Muslim), were non-committed (1 Muslim and 1 Christian), and one Muslim teacher who seemed to be confused (Table 3). Below, we present selected excerpts to illustrate the positions presented in Table 3.

Table 3. Teachers' positions regarding evolution categorized by religious affiliation

	Muslim			Christian	Total
	Shiite	Sunni	Druze		
Accept			5	4	9
Reject	3	1		1	5
Reinterpret	2	1			3
Neutral (Non-committed Confused)		2		1	3

Teachers who accepted evolutionary ideas. Teachers in this category were Druze or Christian. None of the Shiite or Sunni Muslims could be categorized as accepting evolution. The excerpts below illustrate the positions of the teachers in this category. These teachers based their support of evolution on scientific evidence or an NOS argument which suggests that science and religion are two ways of knowing (T6). The following excerpts illustrate the positions of teachers who accepted the theory evolution.

- *Well I think evolution is one way of explaining our existence and the existence of others and there is some evidence when we talk about fossils or other things. I am not very religious so it [evolution] does not create any conflict for me (T8, Druze)*
- *I consider myself a believer, a strong believer in God but I don't think this influences the way I would see the evolutionary theory when you think about it from a nature of science perspective. So, I don't try to mix things [religion and science] together and I don't like mixing things. To me science and religion are two different things and looking for different goals and you do not have to mix them (T6, Christian)*

Teachers who rejected evolutionary ideas presenting arguments from a creation or antievolutionary perspective. The teachers in this category were mostly Shiite and Sunni Muslims who rejected evolution based on their religious beliefs. However, a number of the teachers in this category based their rejection of the theory on inadequate understanding of NOS by indicating that evolution is only a theory (T19) or conceptual difficulties with the theory (T20). The following excerpt illustrates the positions of teachers who rejected the theory evolution.

- *Things might have evolved but this does not mean that the theory is correct... I do not - as a Muslim - believe it at all! Well there is still a gap in the theory. For example the theory of natural selection: scientifically speaking there is a conflict. A giraffe for instance might have developed a long neck either by evolution or by mere chance because of many factors. How come there are some species that do not have long necks? The variety of plants is not a result of evolution but God created them in this way to have a balance in nature (T20, Sunni Muslim).*

Teachers who reinterpreted the theory. Teachers in this category were Shiite and Sunni Muslims. They selected certain aspects of the theory seemingly in an effort to reduce its perceived conflict with their religious beliefs. T15 for example suggested that evolution of animals was acceptable while T3 said that natural selection does not create a conflict for him. The following excerpt illustrates the positions of teachers who reinterpreted the theory of evolution.

- *Concerning animals, evolution is more acceptable ... it makes more sense that animals evolved than to say that humans evolved to me actually. Even to some students, it's easier to understand how animals evolved than humans... I can't relate evolution in general to religious ideas ... They are just opposite or they just contradict each other (T15, Shiite Muslim)*

Teachers who espoused either a non-committed or a confused perspective. There were three teachers in this category, 2 Sunni Muslims and 1 Christian. These teachers were non-committed (T4 and T5) hovering between accepting and rejecting the theory or confused (T1). The following excerpts illustrate the positions of teachers who were either non-committed or confused .

- *I accept it as any other scientific theory. You know I believe both I try to make sense of both, ... I mean I believe that I am created I have the image of my God you know but ...I try to make sense of evolution as a theory, I try to go back maybe to Darwin and I try to analyze what Darwin thought ... you know for him maybe it sounds right... From the religious point of view, I have to be (an antievolutionist) and this is my belief, but from a scientific point of view, you know I cannot be so this is why I don't have really a stand. It definitely creates a conflict, for me I can accept both at the same time... I don't think there is really evidence because if there is evidence why wouldn't we... why wouldn't the church adopt this evidence, you know, how could they deny the presence of such evidence? (T5, Christian)*
- *I am a Muslim, I believe in the Koran that it is a correct book, everything said in the Koran, there are scientific ideas that are written in the Koran. ..Darwin said that we came from ancestors of apes, we were never apes; in a way I believe in this. But according to my religion this is sometimes a conflict for me. I don't believe that Darwin is 100% correct; he has ideas about evolution that are correct but not about being an ape (T1, Sunni Muslim).*

The results presented in Table 3 above show that there might be a pattern regarding the relationship between teachers' religious affiliation and their positions regarding the theory of evolution. Table 2 shows that 9 teachers, who were either Christian or Druze accepted the theory of evolution. The remaining 11 teachers, who were either Sunni or Shiite Muslims, except for 1 Christian teacher either rejected the theory (3 Shiite and 1 Sunni Muslims), reinterpreted it (3 Shiite and 1 Sunni Muslims) or were neutral (2 Sunni Muslims and 1 Christian). However, here also the pattern may not be stable across the population of biology teachers since the number of participants in this study is relative small.

Teachers Objections to the Theory of Evolution

Teachers' objections to the theory of evolution were mainly of three types: those based on conceptual difficulties, those based on religious beliefs, and those based on inadequate understandings of NOS. It is worth noting that a few teachers had one more type of objection. Teacher 20, for example had conceptual difficulties with certain aspects of the theory as illustrated in the excerpt below:

- *For example the theory of natural selection: scientifically speaking there is a conflict. A giraffe for instance might have developed a long neck either by evolution or by mere chance because of many factors. How come there are some species that do not have a long neck! (T20).*

Teachers 5 and 20, however bases her objections to the theory based on her trust in the religious establishment by saying:

- *The variety of plants is not a result of evolution but God created them in this way to have a balance in nature. (T20).*

Finally, several teachers based their objections to the theory of evolution on inadequate understandings of NOS as can be seen in the following excerpts:

- *There is a gap in the theory ... after all it's just a theory (T19)*
- *The theory of evolution is not supported by facts -- it is just a theory (T9)*

Biology University Professors' and Teachers' Positions about Teaching of the Theory of Evolution

Analysis of interview data regarding university professors' and teachers' positions about teaching the theory of evolution produced three categories (What is taught, how evolution is taught, should evolution be taught) under each of which there were several patterns (Table 4). Consequently, interview data from professors and teachers were organized under these categories. In the following paragraphs we present university professors positions followed by those of teachers.

Biology university professors' positions about teaching evolution. While the biology professors differed in their positions regarding the theory of evolution, they all thought that it was necessary to teach the theory because it was essential for understanding biology. Furthermore, except for U7 (Shiite Muslim) who teaches a course on evolution, they all said that they cover certain elements of the theory explicitly in their courses. However, these professors differed in the approach they used when addressing topics related to the theory. University professor 1 (U1), who reinterpreted the theory by rejecting the idea of common ancestry with apes, said that she would provide students with all pertinent information and leave it to them to decide to accept or reject the theory as demonstrated in the excerpt below. At the same time, she suggested that a few topics might be problematic for students, especially when considering the origin of life:

- *If I am one day to teach the theories, I would always present them as they are, even about the origin of life, I would present it as it is and I would say it is up to you to take it or leave it. If we want to be honest, we should not convince students... I mean we should not involve our own beliefs let them choose. Teaching evolution is a little bit critical in some cases when the teachers impose their beliefs on students (U1, Sunni Muslim) ... If we are talking about the origin of life (creation against non creation), definitely, I think students will not be very comfortable, But for the remaining theories of evolution, I cannot see any discrepancy between the religion, any religion, and the science of evolution.*

The second professor who reinterpreted the theory by rejecting the idea of common ancestry with apes (U2) was not as neutral as U1. While emphasizing the importance of the theory of evolution as essential for understanding biology, she seemed to include her own beliefs in teaching the theory as demonstrated in the excerpt below.

- *I introduce the concepts of evolution, the premises of the theory of evolution, the concept of variation and how it links to Mendel's findings. We also talk about the evidence for the theory of evolution, the biochemical evidence, the genetic evidence, the biogeographic evidence, so we talk about the evidence at all levels. And I tell them in a sense that evolution does not contradict with religion ... Evolution is not part of the curricular objective in the courses I give, but I teach it because I believe actually it is at the basis of biology. Evolution is at the basis of understanding many concepts in biology so I strongly believe in these evolutionary trees, that organisms have common ancestor, except for man, keep man on the side... Maybe I am teaching it (evolution) in the wrong way, but this is the way I believe in it. I don't teach that man come from apes, I tell them that this is a wrong theory but I teach it my own way, so they really accept it. I tell them it doesn't contradict religion... I fit evolution into my way of believing and maybe into student's own way of believing...(U2)*

The university professor who reinterpreted the theory by attempting to disentangle the issues of evolution from creation (U5) was supportive of teaching evolution but not necessarily in a separate course as shown in the excerpt below:

- *I think [the curriculum] is fine, we teach evolution; basically it's an elective course. I think this is fine, whether it should be required or not, that's a completely different argument. I doubt that it needs to be a required course per say but it definitely needs to be part of the curriculum and it needs to be introduced in introductory courses and it should be left to the students and their fields of interest whether they want to take courses in evolution or not.*

The university professors who accepted the theory of evolution were all in support of teaching the theory. However, unlike those who reinterpreted the theory they were adamant that the theory be taught as a scientific theory. None of them mentioned the necessity of introducing religious ideas in their courses and they all

emphasized the importance of providing students with tools to help them think about evidence. Below is a typical response:

- *I teach about nine different courses between undergraduate and graduate. In two of these courses, I actually teach the theory of evolution in depth for at least two to three weeks. Although the course is not a course on evolution, I introduce the course by teaching evolution (one is a freshman course, and the other is a senior course on environmental physiology), but I really need to teach the concepts of evolution to actually have the students understand the reasons for physiology being the way it is, physiological properties. Biology cannot be explained without evolution, evolution is the reason we all are the way we are today ... As a scientist and as a teacher, I have to teach my students to believe things when they see them, touch them and understand them ok ... Our job as professors, especially in university not in school, is not to teach our students information; they can go get the information. Our job is to teach them the right way to think and our job is also to teach them that there is a multiplicity of right ways to think (U3)*

Table 4. Themes that emerged from analyzing data related to teaching of evolution

Categories	Themes
What is taught?	<ol style="list-style-type: none"> 1. Not included in the curriculum: Evolution as a topic is not part of the required curriculum. 2. Included in the curriculum: Evolution as a topic is included in the required curriculum. 3. Integrated with other related topics: Evolution is included in the context of discussing other topics such genetics and diversity of life.
How evolution is taught presently?	<ol style="list-style-type: none"> 1. Taught explicitly: Evolution is taught explicitly because it is a component of the required curriculum. 2. Integrated with other topics: Evolution is taught explicitly but briefly when teaching other topics. 3. Taught implicitly: Ideas from the theory are taught without mentioning Darwin or referring to the theory of evolution.
Should it be taught?	<ol style="list-style-type: none"> 1. Evolution should be taught 2. Evolution should be taught along with religious accounts 3. Evolution should not be taught

Biology teachers' positions about teaching evolution. The majority of the teachers (15 teachers, 75%) said that they did not teach the theory of evolution explicitly because it is not part of the Lebanese curriculum (Refer to the section entitled *Context* in this paper). However, a number of them said that they taught specific components of the theory implicitly in the context of other topics as demonstrated in the excerpt below. It is noteworthy, however, that there was no relationship between teachers' position regarding evolution and teaching it implicitly. A few teachers who rejected the theory but said that they taught components of the theory suggested that they accepted these components but not the theory in its totality.

- *Even if it's (theory evolution) not there explicitly, it is there implicitly, because I believe that evolution is the unifying theme of all areas in biology and even if it's not there explicitly in the Lebanese curriculum, I try to bring that issue up from time to time, because sometimes biology questions could be answered in multiple ways. You can have them answered from an evolutionary point of view ... for example, all molecular biology questions could be answered from a biochemical point of view and sometimes could be answered from an evolutionary point of view. (T6, Christian)*

When asked if evolution should be taught, eight of the nine teachers who accepted the theory evolution said that it should be taught in high school because it provides a strong explanatory framework for understanding biology. The only teacher who accepted evolution but said it should not be taught because it is not in the curriculum (T12). The following excerpt illustrates the positions of the teachers in this category.

- *Definitely, it should be included because it is one way of explaining existence and further progresses and species, so it should be given some importance. I think we should give more worth to the theory of evolution in our textbooks and in our classes regardless of the grade level, especially starting grade 10 up till grade 12 because it's when students start questioning and formulating their*

own theories (T8, Druze)

Three of the five teachers who rejected the theory of evolution said that it should not be taught because it conflicts with religious beliefs (2 Shiite and one Sunni Muslims). The following excerpt illustrates their point of view:

- *Evolution should not be taught here because it creates a lot of problems and conflicts. I don't think we should teach evolution because the theory as a principle is not accepted at all by the culture. Religion refuses it (T19, Shiite Muslim).*

The other two teachers, a Shiite Muslim and a Christian said that the theory of evolution should be taught but gave different reasons for why it can be taught. Teacher 17, a Shiite Muslim suggested that it should be taught as a change mechanism:

- *If you consider it from a scientific perspective, then fine, especially if you explain how biology changes and how knowledge changes because of the many variables that affect it (T17, Shiite Muslim).*

Alternatively, T9, a Christian teacher said that students should be provided with evidence and left to decide for themselves if they accept or reject the theory:

- *So at least, let [the students] have the scientific background of what is the theory of evolution. Then they can make their choice, after gaining the knowledge (T9, Christian).*

Teachers who reinterpreted the theory of evolution had different points of view regarding teaching the theory of evolution. While two of them (Shiite Muslims) were against teaching evolution because of its conflict with religion, the third, a Sunni Muslim said that evolution and religious accounts should both be presented and it should be left for the students to decide what position to take as illustrated in the following excerpt from T3:

- *I think evolution should be taught in the Lebanese program. I think the views of religion, they should be explained and, at the same time, the views of the scientists towards evolution and with all the theories of evolution (T3, Sunni Muslim).*

Finally, two out of the three Sunni Muslim teachers who were non-committed said that the theory of evolution should be taught mainly because we are not sure that Darwin was wrong and because religion should not interfere with science.

- *You tell students that they have to learn about Darwin because he's a scientist, he's a famous person, we can't say he's wrong; I have to put religion aside. Because if I am a science teacher and I have a scientific mind, I have to let them learn about Darwin (T1, Sunni Muslim)... Religion is something to learn at home, but also we have to learn about most of the scientists, whether they are foreign scientist or Arab or Lebanese.*

The second Sunni teacher suggested that the theory should be taught even though it might create conflict:

- *For religious people the theory will create a conflict, yes definitely. some will not even hear what you're talking about; some will say, well in the science class this is what it means, in the religion this is what it means and symbolism; and you have some people who would want to, and make sure that everything is consistent, and these are the students that will really have problems with the theory... We must teach it because it is the overarching framework of biology. If you want to have biology concepts a whole you need the big theory that explains all the phenomena that take place in biology.*

The Christian teacher in this group was not sure whether or not the theory should be taught as illustrated in the following excerpts

- *[Students] should be exposed [to the theory] just to have an idea, but it's not in our [Lebanese] curriculum. So at least, let [the students] have the scientific background of what is the theory of evolution. Then they can make their choice, after gaining the knowledge (T9, Christian).*

Conclusions and Discussion

Results indicate that religion seems to play an important role in biology teachers' and professors' positions regarding evolution especially that results indicated that the majority who rejected or reinterpreted the theory were Muslims. Most participants' religious orientations seemed to influence their acceptance of evolution. Five of the 20 teachers (4 Muslims) rejected evolution because it contradicted their religious beliefs. Three Muslim teachers reinterpreted the theory of evolution arguing from a compromise perspective and suggesting that evolution did not include humans, citing verses from the Quran to support their positions. Three teachers did not want to commit to any position regarding evolution. Importantly, scientific evidence did not seem to influence the thinking of those who rejected or reinterpreted the theory of evolution. Additionally, some objections to evolution indicated that many participants held misconceptions regarding NOS that they to discredit the theory of evolution by suggesting that it was 'just a theory'. Interestingly, some university professors also echoed teachers' objections to evolution. Two Muslim professors reinterpreted the theory of evolution arguing from a compromise perspective that evolution did not include humans. Conversely, 9 out of 20 teachers (5 Christian, 4 Druze Muslims) and four of the seven university professors accepted evolution (2 Christian, 1 Shiite, and 1 agnostic). Our analysis shows that religious beliefs and lack of a clear understanding of NOS determined the positions of many Muslim teachers and professors regarding evolution. A similar study probing Canadian and Pakistani Muslim science teachers' and scientists' understanding of evolution found that teachers mostly tended to reject human evolution based on their religious beliefs.

Research shows that teachers' beliefs and attitudes are crucial determinants of their pedagogical decisions with teachers' acceptance or rejection of evolution impacting the treatment of evolution in their instructional practice. We found that a number of participants advocated the teaching of religious accounts including "Intelligent Design." Teachers who rejected or reinterpreted the theory of evolution said that it should not be taught (3), evolution and creationism should be given equal time (2), or evolution should be taught while allowing students to take their own stand. Teachers implementing the national curriculum said that they did not teach evolution; they rather integrated elements from the theory when teaching genetics or taught evolutionary concepts without using the word "evolution". Teachers implementing foreign curricula taught evolution explicitly. Those who rejected evolution either presented a religious explanation along with evolution or taught a reinterpretation of the theory. Two professors indicated that they taught evolution explicitly, while the rest (5) said that they integrated it in teaching other biology content. One of the Muslim professors reported that she stressed "the role of God in creation." It seems that many years of studying and teaching biology has not had a transformative effect on how a number of teachers and professors think about evolution.

Implications

This study has practical implications for teacher development and science education. If this study's findings are representative of science teachers throughout this country, it appears that those teachers would benefit from more training in evolutionary science and related pedagogical methods. It also informs science teachers in countries where Muslims are a minority about how Muslim teachers might think about evolution and its teaching, thus facilitating a greater Western understanding of the diversity of Islamic thought on evolution and evolution education.

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EPISTEMOLOGICAL BELIEFS IN SCIENCE: AN EXPLORATORY STUDY OF LEBANESE UNIVERSITY STUDENTS' EPISTEMOLOGIES

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Abstract

The purpose of this study was to explore Lebanese university students' epistemologies of science. Hofer's framework on personal epistemology was adopted in the present study. Participants were two hundred and thirteen students in their first year of science-related studies at a private university in Beirut. Two instruments were used for data collection: The science-focused epistemological beliefs questionnaire (Hofer, 2000) and a seven-item instrument adapted from the modified version of the "Views on science technology–society" (VOSTS) (Dogan & Abd-El-Khalick, 2008), and an additional item developed by the authors. Thirty students were purposively selected for completing the second instrument followed by a semi-structured interview. Data analysis yielded the following assertions: 1) Scientific knowledge is liable to change, 2) The source of scientists' knowledge is inherent to human's construction whereas the source of personal knowledge is independent from human subjectivity and based on external authority, 3) Scientific knowledge is proven and validated through the concerted effort of scientists and 4) Absolute truth cannot be attained because of the lack of means to access knowledge. Findings highlighted the need to foster an academic culture that promotes students' epistemologies. Recommendations were suggested to explicitly address the nature and processes of science in curricula and instruction.

Introduction and Rationale

Individual ideas and beliefs about the nature of knowledge and knowing have been the subject of extensive research under the umbrella of epistemology. Many terms have been used to label these ideas and beliefs such as: reflective judgment, ways of knowing, epistemic beliefs and epistemological reflection (Hofer, 2001). Research on personal epistemology, regardless of the terminology used, comprises some typical elements that characterize it, including ways of knowledge construction, source of knowledge, evaluation of knowledge, and progression and development of knowledge.

As reviewed by Hofer (2001), personal epistemology research has been conceptualized from two different perspectives: a developmental perspective and an independent beliefs perspective. The first approach, rooted in the traditions of cognitive development, perceives the progression of one's ideas about knowledge and knowing as occurring in successive stages. A primary assumption at the heart of this work is that the major changes throughout childhood and adolescence are associated with changes in the relationship between the knower and the known. These maturational changes follow a specific path or sequence from a dualistic perspective of knowledge (knowledge is right or wrong, black or white), to multiplism (one opinion is as good as another), and ultimately to a commitment within relativism (an acknowledgement of multiple point of views with justified commitment to one of them). This line of research originated from the work of Perry (1970) and his team, who established "the Perry's scheme", and was later adopted in other models including "women's ways of knowing", "the epistemological

development model”, “reflective judgment” and Kuhn’s levels of epistemological perspectives underlying argumentative thinking.

The second approach to epistemological research, pioneered by Schommer (1994), recognizes beliefs about knowledge and learning as more or less independent rather than developing concurrently. Instead of determining a sequence of epistemological growth, Schommer (1990) designed an instrument to assess epistemological dimensions by identifying four aspects of knowledge acquisition: stability, structure, speed and control. These dimensions are viewed to vary along a continuum from naïve to sophisticated. Other researchers followed up Schommer’s work and used it to explicitly identify the relation between epistemology and learning (Hofer, 2001).

However, it appears that neither the developmental approach nor the independent beliefs approach account for the structural nature of personal epistemology according to recent research in cognitive psychology and science learning (Hofer, 2001). In contrast to both these approaches, Hofer and Pintrich (1997) conceptualize ideas about knowledge and knowing as structured in the form of “personal theories”. To represent personal epistemology as a construct based on this perspective, Hofer (2001) identifies dimensions that relate to this construct and categorizes them in two branches: beliefs about the nature of knowledge and beliefs about the process of knowing. The first branch includes the dimensions *certainty of knowledge* (knowledge as fixed and certain versus knowledge as tentative and evolving) and *simplicity of knowledge* (knowledge consists of isolated discrete truths or facts versus knowledge as interrelated ideas and concepts). The second branch relates to beliefs about the nature or process of knowing or how one comes to know and this comprises the dimensions *source of knowledge* (knowledge as produced by some external authority versus knowledge as human construction produced in systematic and generic ways) and *justification of knowledge* (science as objective reality versus science as evaluated by agreed-upon methods based on evidence). Hofer (2000) reconceptualized these dimensions by integrating *simplicity and certainty* under one category, keeping *source* and *justification*, and adding a fourth dimension, *attainability of knowledge* (truth in science can be attained *versus* truth in science is unattainable). Conceptualizing epistemology in the form of organized theories implies that one’s epistemological perspectives along the various dimensions are integrated and interrelated, allows for a better understanding of the mechanisms of knowledge acquisition and change, as well as acknowledges the domain-specificity of epistemological beliefs thus considering them as responsive to the context and discipline (Hofer, 2001).

Associations between context and personal epistemology have been the object of considerable effort for researchers seeking to understand the interplay between culture and epistemological beliefs. Understanding this interaction stems from comparative studies including cross-cultural (e.g. Karabenick & Moosa, 2005) or country-specific studies (e.g. Sutherland & Dennick, 2002). Another line of research focused on exploring the way in which the particularities of a culture shape the epistemological views of people in that culture. Since most of this research has been conducted in the West, it is important to conduct similar studies in non-Western cultures, such as the Middle East, to shed light on the role of the cultural sphere on the development of such beliefs. In fact, in the Middle East, very few studies have investigated epistemological beliefs (e.g. Karabenick & Moosa, 2005). In Lebanon, a study conducted by BouJaoude and Abd-El-Khalick (1996) explored middle school students perceptions about the definition and purpose of science. Findings reveal that students viewed science as a vehicle to achieve a higher social status through science-related careers, a belief in which they have been socialized. Although this and similar studies in Lebanon probed students’ views about the nature of science, the present study extends this line of research by providing a broader view of epistemologies encompassing both, beliefs about nature of science and beliefs about science processes. Being specifically sensitive to the cultural and social context, Hofer’s framework on personal epistemology is adopted in the present study for assessing

Lebanese sophomore students' epistemologies. With 17 different religious sects, Lebanon provides an interesting context for epistemological research given its diverse and pluralistic societal structure. Such a heterogeneous composition of the society made Lebanon vulnerable to the civil war that ravaged the country from 1975-1990 and whose remnants persist nowadays in the form of religious and political fractures among Lebanese citizens. These fractures are exemplified with the dominance of authority figures (Zou'ama) and followers swearing allegiance to them. While exploring Lebanese university students' epistemologies of science, we will keep in mind these particular aspects of the Lebanese society that might predict students' beliefs about scientific knowledge.

Methods

The present research aims at exploring university students' epistemologies in the context of an American university in the area of Beirut, Lebanon. Two hundred thirteen first year university students participated in the study (59.5% females), all of whom are pursuing science-related studies (53% biology, 11.9% chemistry, 17.8% nutrition and 17.3% other scientific fields). Approximately 47% were Muslim, 29.1% Christian and the rest, 3.3%, belonged to other religions while 20.7% did not specify their religions.

Two instruments were used for data collection. The first was *The Science-Focused Epistemological Beliefs Questionnaire* developed by Hofer (2000). This instrument yielded four scores along the dimensions: 1) certainty/simplicity, 2) source, 3) justification and 4) attainability. Scores on each of these dimensions were divided into three ranges: lower third (informed), middle third (mixed), and upper third (naïve). The second instrument comprised eight items, seven of which were adapted from the modified version of the "Views on science technology–society" (VOSTS) by Dogan and Abd-El-Khalick (2008) in addition to an eighth item developed and validated by the authors. This instrument was used to tap into students' epistemologies along the four dimensions and particularly to prompt them to express their views about science in a specific context. The instrument was piloted prior to the study. All participants answered Hofer's questionnaire, and based on their responses, thirty students representing the continuum naïve/informed were purposively selected for completing the second instrument followed by a semi-structured interview. Data from the interviews were transcribed and coded along the four dimensions. The researchers worked together on coding three interviews and agreed on the scoring scheme. Afterwards, they worked separately on scoring the rest of the interviews. The researchers then sat together to share their coding and discussed inconsistencies until agreement was reached. Thus, inter-rater reliability was established.

Results

Students' epistemological beliefs were quantitatively assessed using Hofer's questionnaire. These beliefs were classified as either sophisticated, mixed or naïve based on students' scores on the Likert scale reflective of Hofer's categorization. A frequency count was carried out for each of the four epistemological dimensions. Moreover, students' responses along the four epistemological dimensions were analyzed with regards to gender, field of study and religion. The findings are summarized in the following tables (Tables 2, 3 and 4).

Table 1. Percentage distribution of epistemological beliefs along the continuum naïve- sophisticated

	Certainty/Simplicity	Source	Justification	Attainability
Sophisticated	61.5	28.2	32.4	56.5
Mixed	37.6	69.9	65.2	41.5
Naïve	1.0	1.9	2.5	1.9
Total (in %)	100	100	100	100

As can be seen in the table above (table 1), students' responses clustered mainly at the mixed and sophisticated parts of the continuum. For the two dimensions certainty/simplicity and attainability, students showed more sophistication compared to the other two dimensions source and justification, where students' beliefs were mostly mixed.

Table 2. Percentages of students' epistemological beliefs based on gender

Dimension	Certainty/Simplicity		Source		Justification		Attainability	
	M	F	M	F	M	F	M	F
Sophisticated	41.1	58.9	50.8	49.2	40.9	59.1	38.8	61.2
Mixed	38.2	61.8	37.1	62.9	42.7	57.3	41.7	58.3
Naïve	50.0	50.0	25.0	75.0	25.0	75.0	50.0	50.0

*M = Male; F = Female

No significant difference was found on epistemological dimensions with regards to gender ($\chi^2=0.88 >0.05$). The literature concerned with gender differences across epistemic beliefs is inconclusive at times suggesting a difference between genders at others revealing no differences (Hofer, 2000). For the current study, a possible explanation of the findings lies in the fact that the Lebanese educational system is a liberal system, in which males and females tend to similarly pursue science related studies.

Students' epistemological beliefs were also assessed in relation to students' fields of study (major). The results are displayed in table 3 below.

Table 3. Percentages of students' epistemological beliefs based on major

Dimension	Certainty/Simplicity				Source				Justification				Attainability			
	B	C	N	O	B	C	N	O	B	C	N	O	B	C	N	O
Sophisticated	64.5	9.9	11.6	14.0	69.0	5.2	13.8	12.0	50.8	13.8	20.0	15.4	65.2	8.0	14.3	12.5
Mixed	37.5	11.1	30.6	20.8	48.9	13.9	19.0	18.2	55.2	8.0	16.8	20.0	38.3	13.6	24.7	23.4
Naïve	0.0	0.0	0.0	100	0.0	0.0	50.0	50.0	50.0	25.0	25.0	0.0	25.0	50.0	0.0	25.0

*B = Biology; C = Chemistry; N = Nutrition; O = Others

As shown in Table 3, there was a significant difference in epistemological beliefs between majors with regards to the dimensions of certainty/simplicity ($\chi^2=0.00$), source ($\chi^2=0.02$) and attainability ($\chi^2=0.00$). Biology major students had more sophisticated views than students majoring in other fields with regards to those three dimensions. This finding invites to further investigate the contextual factors that might explain why biology students hold more sophisticated beliefs when compared to students in other majors.

Also, a significant difference was found between religions on certainty ($\chi^2=0.00$) and justification ($\chi^2=0.05$) (table 4).

Table 4. Percentages of students' epistemological beliefs based on religion

Dimension	Certainty/Simplicity			Source			Justification			Attainability		
	M	C	O	M	C	O	M	C	O	M	C	O
Sophisticated	57.4	39.6	3.0	58.7	37.0	4.3	70.2	22.8	7.0	63.7	34.3	2.0
Mixed	65.0	31.7	3.3	59.8	37.6	2.6	54.5	43.6	2.0	52.4	41.3	6.3
Naïve	0.0	50.0	50.0	33.3	33.3	33.3	33.3	66.7	0.0	50.0	50.0	0.0

*M = Muslim; C = Christian; O = Other

The results presented in table 4 above revealed that Muslims in the studied sample were more sophisticated than Christians on both dimensions. The influence of religion on epistemic beliefs can be understood with reference to the context of Lebanon where people are aware of their religious beliefs and incorporate these beliefs in their daily life decisions; Previous studies did not explicitly investigate differences in epistemological beliefs based on religious backgrounds; thus, this study sets the ground for further investigation of the possible reasons for the observed differences as well as potential implications.

Students' epistemological beliefs were also qualitatively assessed using a questionnaire adapted from Dogan and Abd-El-Khalick (2008) followed by a semi-structured interview. Data from the thirty interviews was analyzed and, for each of the four dimensions, students' answers were coded along the continuum naïve-sophisticated. This continuum was developed based on a coding scheme that was derived using a constant comparison approach to analyzing students' responses during the interview.

Dimension Certainty/Simplicity

Beliefs related to this dimension consist of how scientific knowledge is structured and whether or not it changes as well as how it changes. Despite the fact that the interview lends itself to reveal epistemological beliefs related to the dimension certainty/simplicity as one (i.e. a unified dimension), very few students attended to attributes related to simplicity. Students at the sophisticated end revealed an understanding that scientific knowledge changes either by adding to a fixed 'core' or by being refuted:

"I will go back to the atomic model. As technology advanced, some theories were disproved. The 1st Bohr model was disproved for some atoms and was applied for one element; it didn't apply for other elements. Now we might have a theory that applies, but in future it could be disproved or narrowed down for a specific thing. Everything can be disproved. Theories can be modified... and could be subject to expansion as well. For example my mom is a doctor, what she studied in university, we are studying like twice now in addition to some info that she doesn't know about" (Interview 6)

Some of them emphasized that change also occurs at the level of perception and interpretations through revisiting assumptions and mental models:

"Nothing is for granted, [a theory] is something that hasn't been proved wrong yet; so scientific knowledge might change as we reinterpret it and discover something new" (Interview 19)

Students at the naïve end perceived knowledge as changing by being added upon for the sake of improvement (making it more useful) and refinement (more accurate) without affecting the ‘core’ or the ‘building blocks’:

*“Further research will change the facts I’m studying... modifying and correcting errors, but not refuting previous knowledge”
(Interview 3)*

Many drew on examples from the history of science to emphasize the evolutionary rather than revolutionary aspect of change.

“[...] for example, the previous model of the atom is now improve one and not considered a wrong one because at least they took the idea of having the electrons and protons, then they changed their location in the model” (Interview 4)

Only one student was explicitly committed to a view that science is constant and does not change. Students with mixed views acknowledged that scientific knowledge changes by both addition and refutation stressing that the change is driven solely by external agents such as discoveries, events, parameters and breakthroughs without appealing to changes in assumptions and interpretations.

“[...] Knowledge might change, because the old knowledge will be reconsidered in light of new discoveries: If you have something on the table and you make an observation then you observe it another time with a change in the atmosphere... you will attain a new kind of knowledge because the old knowledge has been affected by the environment” (Interview 15).

Assertion 1: *Scientific knowledge is liable to change.* Most students perceive of change as expansion, improvement or refinement of scientific knowledge. Besides, students believe that scientific knowledge can ‘change’ as a result of technological advancements, attending to errors and social collaboration. Moreover, when students recognize the role of unplanned occurrences in the advancement of science, their interpretation of the scientists’ understanding of and response to such occurrences is linear. Change is induced by errors / mistakes that are mostly perceived as experimental, leading to advancement of science. This might reflect a naïve understanding of errors seen exclusively as either mistakes or related to lab work (experimental/instrumental constraints):

“When they [scientists] check their work from each other... it’s hard to find many scientists making the same errors. So they check errors to be found and changed... like any error: measurement, experimental... in their observations there is no much error, but in their experiments, there are” (Interview 2)

“Scientific knowledge changes; like for example, the dual nature of light ... it’s a complete change... this was maybe due to better methods of investigation, equipment... people maybe found errors from before... and have built on them” (Interview 17)

Dimension Source

Beliefs related to this dimension pertain to the source of knowledge production. Beliefs related to source of knowledge fell under two categories: source of personal knowledge and source of scientists’ knowledge, each varying between two extremes: extrinsic (as residing outside the human construction) versus intrinsic source of knowledge (within the realm of human construction).

Source of scientists’ knowledge

Sophisticated views were characterized by an understanding of science as being subjective, affected by human imagination and creativity (in terms of ideas as well as methods) and by human perspective and background.

“Scientists get the laws from their minds but based on what nature does...under the tree there is no law! There is evidence that will lead him [the scientist] to deduce the law” (Interview 1)

On the other hand, naïve views were mostly centered on the idea that the source of knowledge is independent from human subjectivity:

“When scientists come up with classifications, they observe facts and classify them. They simply match nature” (Interview 30)

Students with mixed views believed that observations are independent of human subjectivity whereas interpretations and explanations might be related to human inference.

“Scientists’ observations will be the same but their interpretation will be different such as this paper is here. But what is written on the paper is to be interpreted differently by each.” (Interview 3)

In this example, the student was trying to draw an analogy to clarify his thought: We can all see what is written on the paper in the same way (i.e. similar observations) , however the way we make sense and understand what is written can be completely different from one another (i.e. different explanations or interpretations).

Source of personal knowledge

Students with sophisticated views believed that the source of personal knowledge is the individuals themselves through their engagement in a process of critical inquiry in their attempt for meaning-making.

“If I’m not convinced with the answer from the book, I won’t put it in my exam; after the exam, I read about it... I have curiosity, so I might read a book. If it is still not logical, I read a graduate book or I’ll do a research using the internet” (Interview 12)

However, students with naïve views expressed that the source of personal knowledge comes from external authority (teacher, book, scientist, etc...):

“Even if my answer is different from the one in the book, I will choose the answer from the book. Scientists said that and I’m not qualified to change what scientists said” (Interview 2)

Mixed views varied between the two extremes revealing some commitment to authority while leaving some space for meaning making process:

“In the exam, if I’m not convinced with the answer from the book, I’ll choose the book answer, it might be right... I didn’t research it, I didn’t encounter it before. When I’m done with the exam, I’ll go to the teacher to ask him about it or I might even try it... I might do it personally to see what happens and if it is not possible to do that, I’ll research it through internet” (Interview 1)

It was noticed that, interestingly, when prompted purposefully to think through a critical authentic/genuine science situation representing a relevant experience to students’ life such as an exam, students tended to compartmentalize their beliefs regarding what is a reliable source of knowledge:

“[If it’s contrary to what I said], I would rely on the textbook, especially for an exam. But after, in class discussion, I’ll choose my answer. I will ask the professor and research to get a convincing interpretation [...] something understandable and logical” (Interview 5)

Assertion 2: *The source of scientists' knowledge is inherent to human's construction whereas the source of personal knowledge is independent from human subjectivity and based on external authority.* Students tend to be more sophisticated when expressing their beliefs regarding the source of scientists' knowledge and less so when they talk about the source of their personal knowledge. Naïve beliefs on the source of personal knowledge could be related to Lebanese students studying science in a foreign language (French or English) and not in their mother tongue language (Arabic). Furthermore, less emphasis in school science is given on the scientific achievement of Arab scientists let alone Lebanese scientists. Consequently, students view scientists as "aliens" and can't identify themselves as critical thinkers who can question science. Another explanation for why students think that the source of personal knowledge resides outside of human's subjectivity stems from the observation that Lebanese tend to allocate referents for every other aspect of their lives whether it be political, religious or even social.

Dimension Justification

Beliefs related to this dimension pertain to the justification and validation of knowledge. Beliefs about justification of knowledge varied between extremes: critical evaluation of knowledge claims versus blind dependence on and trust in the scientific method for justification. Students with sophisticated views believed that knowledge is justified and supported with reference to evidence/proof:

"I think that for scientific information to be correct, this has nothing to do with the method that was used. For example if you have two things, two scientific explorations, both proven scientifically then it doesn't matter if they were found by error or by using the scientific method as long as they are both proven and supported by evidence" (Interview 6)

When talking about justification, some alluded to the idea that the scientific method becomes a habit of the mind for the scientist:

"All scientists apply this method even if unconsciously. It is very comprehensive and can be applied to any field in science even in evolution and astronomy but with some modification... One can make additions to it with originality... even for knowledge derived from accidents, I don't believe in that; you might think it's accident, but actually it's based on many trials and on scientific methods" (Interview 8)

At the other end, naïve views reflected the impact of the hegemony of the scientific method for justifying knowledge.

"Even if scientists discover something by accident, they continue with the scientific method to validate it because it works most of the time... so it should be used... that's science" (Interview 17)

Justification of knowledge was conceived exclusively in terms of reducing uncertainty and increasing accuracy within an algorithmic approach with the focus on the necessity of repetition.

"Most scientists will follow the steps of the scientific method because it consists of steps. Scientists repeat the same experiment several times until they reduce errors to the maximum and come up with a theory" (Interview 4)

Students with mixed views revealed a commitment to the idea of a step-wise method with acknowledgment of the possibility of various scientific methods:

"To make a breakthrough, scientists don't always depend on methods that others follow; previous ways can be primitive [...] but there must be a method to be followed. By adding new steps to it, the scientific method does not become a new method: we use same basic steps but different ways of application" (Interview 20)

Assertion 3: *Scientific knowledge is proven and validated through the concerted effort of scientists.* Students believe that scientific knowledge becomes valid when peer reviewed and approved by the scientific community. They conceptualize this work as a linear process of knowledge production following specific steps and procedures portraying students' adherence to the traditional "Experimental Method". Moreover, scientific claims are accepted only after repeated experiments and/or observations produce results in support of claims. This assertion reflects the hegemony of the experimental method; science knowledge is subject to scrutiny through the use of the experimental method; when scientists agree on the results derived from the experimental method, the knowledge is validated.

Dimension Attainability of Absolute Truth

This dimension refers to students' beliefs about the accessibility of absolute truth. Beliefs clustered at two ends: either at the sophisticated end admitting the existing of relative truth, or at the naïve end acknowledging an absolute truth. On the sophisticated end, beliefs about attainability were related to the idea that absolute truth is unattainable by referring to the prevalence of subjectivity and perspectivism in knowledge construction leading to multiple realities and relative truths:

"When the scientists have different theories, each one will rely on his theory and discover different things even if they are working on the same thing, each one will concentrate on his major/theory. They may arrive to different results but both could be true somehow" (Interview 24)

On the naïve end, students believed that absolute truth cannot be reached, however not because absolute truth doesn't exist as a concept, rather because of a lack of access to knowledge due to ignorance, technological hindrances or superstition and religious beliefs:

"[...] there are some hidden facts so we as humans can't reach the truth because it is beyond our capabilities or reach and science is not so accurate to know everything. God knows everything" (Interview 14)

Others believed in the existence of absolute truth which can be attained:

"I think that even if scientists have different beliefs, there are facts and they [scientists] should meet at a single unified idea at the end. They can observe in different views, but they must reach the same interpretation: the truth" (Interview 23)

Assertion 4: *Absolute truth cannot be attained because of the lack of means to access knowledge.* Most students believed that absolute truth can't be reached particularly because scientists lack the resources to reach that truth and not because the absolute truth itself is nonexistent. This finding could be related to students' lack of knowledge about the philosophy of science and to the fact that the idea of truth might not be appropriately addressed in the science classroom. It is worthy to note that no students had mixed beliefs about attainability which reflects a commitment to either extreme.

In sum, the findings from the quantitative analysis revealed that the majority of the students expressed sophisticated beliefs based on Hofer's characterization along the four dimensions whereas most of the qualitative data reflected naïve/mixed portraits of these beliefs. In what follows, we advance an explanation to account for this apparent discrepancy entailing implications and recommendations that can inform both further research and instructional practices.

Conclusion and Implications

As the findings of this study revealed, it appears that the qualitative and quantitative data are not well aligned. In an attempt to explain this discrepancy, two interpretations are offered which are open to further investigation.

First, the qualitative data from the interview shed light on students' difficulty in expressing epistemic beliefs. This difficulty might have led to the observed difference in the types of beliefs articulated in the interviews and

those portrayed by Hofer's questionnaire. Two factors can be responsible for this difficulty. The first is the lack of appropriate terminology and language reflected by students' confusion with respect to terms such as observation, error, mistake and evidence. The second factor is related to students' lack of the necessary metacognitive tools that help them bring these beliefs to an awareness level and articulate them. More research on sources of students' difficulties in expressing their epistemic beliefs is hence needed to identify these sources and suggest ways to alleviate them. Such research would have direct implications on instructional practices. Indeed, the current research emphasized the need for teachers to focus on the accurate use of terminology and to promote reflective and metacognitive routines through explicitly teaching about the nature and processes of scientific knowledge (i.e. Yore *et al*, 2004; Yore & Treagust (2006)).

A second possible interpretation of the discrepancy between quantitative and qualitative data stems from the use of the instrument by adopting the factors that loaded on the four dimensions in Hofer's validation of the instrument in the context of the U.S.A. This motivates future research to conduct a factor analysis to empirically validate this instrument in the context of Lebanon to account for the specificity of cultural and contextual factors in shaping students' epistemologies.

This research sheds light on the fact that students entering university do not have a well-developed understanding of the nature and processes of science. Findings highlight the need to foster an academic culture that promotes students' epistemologies. Hence, curricula and instruction should explicitly address the nature and processes of science, while accounting for the peculiarities of the culture and context in which these epistemologies are evolving.

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AN ANALYSIS OF STATUS AND OBSTACLES OF IMPLEMENTATION OF HISTORY AND PHILOSOPHY OF SCIENCE IN SCIENCE EDUCATION

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Abstract

Science educators often have stressed the merits of an approach for teaching and learning with history and philosophy of science (HPS). Advantages for a deeper understanding of scientific ideas and conceptual change have been indicated in favor of this approach as well as support for learning about the nature of science. Nevertheless, positive effects assigned to HPS sharply contrast with a lack of significance for the practice of science teaching and curricular development. In this paper, an analysis motivated by the results of national conferences held in several countries within the framework of a European project called HIPST - History and Philosophy in Science Teaching of the current state of implementation will be presented in order to gain a deeper understanding of science teachers' hesitation or refusal of teaching science with HPS. Experts from several fields including science education, science museums and school science administration analyzed collaboratively the status of implementation of HPS in different countries. The analysis will be enlarged and deepened by an examination of boundary conditions, which prevent science teachers from using HPS approaches for their teaching. It will be shown how the HIPST project considers these boundary conditions for the benefit of the development of case studies for teaching and learning science with HPS.

Introduction

Teaching and learning science with history and philosophy of science (HPS) has a long tradition (overview e.g. Matthews, 1994). Science educators often have stressed the merits of this approach for teaching and learning about science as a process (e.g. Matthews, 1994, Millar & Driver, 1987). Advantages for a deeper understanding of scientific ideas and conceptual change have been indicated in favor of this approach (Seroglou, Koumaras, & Tselfes, 1998, van Driel, De Vos, & Verloop, 1998, Wandersee, 1986) as well as support for learning about the nature of science (NOS) (Galili & Hazan, 2001, Irwin, 2000, Dedes & Ravanis, 2008, Lin & Chen, 2002, Solomon, Duveen, Scot, & McCarthy, 1992). Researchers also pointed out benefits for fostering public understanding of science (e.g. Solomon, 1997) and positive effects on students' attitudes towards science (Solbes & Traver, 2003, Mamlok-Naaman, Ben-Zvi, Hofstein, Menis, & Erduran, 2005). All these effects assigned to HPS sharply contrast with a lack of significance for the practice of science teachers and curricular development. The same holds for contemporary textbooks in science education. They hardly target on the historical development of science, but often portray science in a distorted and a-historical way. Science is demonstrated as a continuous process leading straightforward to the knowledge scientists currently believe to be true (Abd-El-Khalick & Waters, 2008, Irez, 2008, Pagliarini & Silva, 2007). Monk and Osborne (1997: 407) therefore conclude that "attempts to produce structured courses that put history at the center of the enterprise have enjoyed only marginal success". The status of implementation of HPS is obviously weak.

In order to analyze the current state of implementation of HPS in science teaching, national conferences in several countries have been held within the framework of a European project called HIPST: History and Philosophy in Science Teaching (Höttecke & Rieß, in print, see also <http://hipst.ed.ed.auth.gr>). The project aims at a more effective strategy towards implementing HPS in science education and comprises 10 groups from 8 European countries. The HIPST project is by and large concerned with the development and implementation of case studies for teaching and learning science with HPS. The materials are developed, evaluated and refined within a collaborative developmental model. The model aims at an integration of researchers and practitioners' perspectives on HPS and science teaching in order to develop research-based curricular innovations with a high degree of adequacy from both perspectives involved.

Experts from science education, science museums, science teaching and school science administration analyzed the status of implementation during several national conferences held in each participating country¹. Results summarize central problems of implementation: Participants of the conferences criticized a lack of a sustainable concept of how to properly implement HPS in science teaching in their countries. Moreover, they stressed that HPS has no important role in official science curricula and is hardly implemented in teaching standard documents, textbooks and educational material. A lack of accessibility of high quality educational materials was concerned as a major reason for the deficient role of HPS in school science practice. Furthermore, it was stressed that HPS in textbooks usually appears separated from scientific content, which leads to the impression that HPS content is dispensable. The conference attendants also stressed that a lack of implementing HPS is due to an overstuffed curriculum and, thus, a lack of time for HPS-oriented teaching. The role of HPS is often restricted to shortcut presentations, which present distorted views about science. They criticized that HPS is usually restricted to demonstrating a contrast to our modern and more elaborated views. Partners pointed out that a "usual science teacher" instead is very often neither interested nor competent in teaching HPS; those who actually make use of HPS are interested and motivated above the average. The participants of national conferences also agreed that teachers usually have no clue of how HPS might help to teach scientific content, while teachers regard the latter as the most important objective of their own teaching. Its use is restricted to an introduction of a new topic to teach, as an anecdote or to introduce and underline a new model with a historic background. In general there is a lack of teaching skills necessary for a successful HPS approach as inquiry based teaching, storytelling, writing role-play scenarios and directing students performances, moderating discussions among students. To sum up, it is still a challenge to develop strategies on implementing HPS in school science teaching. A deeper understanding of science teachers' hesitation or refusal of teaching science with HPS including knowledge about the requirements for their professional development is a prerequisite for the development of effective developmental and implementation strategies. Current and future projects on developing curricular innovations integrating HPS have to take these obstacles into account in order to be successful. This paper is concerned with an analysis of obstacles for an effective implementation of HPS and on demonstrating how the HIPST project takes these obstacles into account.

A lack of implementation strategies for HPS

Even though many scholars in the field of history and philosophy in science teaching (HPSST) have argued for the benefit of implementing HPS in school science teaching, the actual state of implementation is poor (Monk & Osborne, 1997). The general problem of how to connect curricular innovation with teaching practice becomes evident for implementing HPS approaches like any other curricular innovation. Generally speaking, teachers are the gatekeepers of their classrooms and curricular innovations (Barab & Luehmann, 2003). Thus, their perspectives and potentials shape the process of implementation. A curricular innovation communicated to practitioners can differ substantially from the curricular innovations actually enacted by them thereafter (Reinmann-Rothmeier & Mandl, 1998). One major reason for that is that researchers and curriculum designers on one side and practitioners on the

¹ Reports on national conferences cited here have been thankfully provided by P. Brenni (Fondazione Scienza e Tecnica, Florence, Italy), D. Höttecke (University of Bremen, Germany), I. Galili (Hebrew University of Jerusalem, Israel), R. Coelho (University of Lisbon, Portugal) and J. Turlo (University of Torun, Poland).

other suffer from a “difference in norms, rewards and working arrangements” (Huberman, 1993: 2). Hence, the process of implementing a curricular innovation has to be designed in a way which enables practitioners to relate an innovation designed to their every-day practice and skills as well as to their beliefs about teaching, learning, epistemology, curriculum and the general role of innovations. For instance, innovative ideas for teaching and learning derived from model experiments cannot be transferred to a generalized and undistorted practice of teaching (e.g. Euler & Sloane, 1998). Top-down strategies generally presuppose that curricular innovations can be designed by groups of experts and fruitfully implemented thereafter. Even though top-down strategies of development and implementation have the advantage of being highly adapted to the objectives of the respective experts (e.g. researchers and curriculum developers) and being justified soundly, a rubber-stamping approach aiming at implementing innovations without considering the multiplicity of different contexts is in danger to fail (Barab & Luchmann, 2003).

Instead, a more refined strategy of implementation has to be chosen in order to integrate and harmonize the perspectives and potentials of all agents involved, including researchers and teachers. This strategy has been called symbiotic (Gräsel & Parchmann, 2004) and aims at a high degree of adaption of the curriculum designed to the curriculum enacted. A comparison of different strategies is summarized in table 1. According to a symbiotic strategy curricular innovations consider real problems of teaching practice. The basic idea is that an innovation should offer a solution to a problem practitioners feel to have. Unsuccessful strategies of implementation often suffer from solving problems, which do merely exist in researchers’ or administrative perspectives, but vanish from a teachers’ perspective. According to a symbiotic strategy researchers and teachers collaborate on the design and implementation of a curricular innovation. This strategy aims at a mixture of expertise towards a research-based and practice-oriented developmental strategy.

Table 1. Comparison of implementation strategies.

	Top-down	Symbiotic	Bottom-up
Advantages	<ul style="list-style-type: none"> –highly adapted to objectives of researchers and curriculum developers –innovation transposes results from research and development –high degree of integrity of curriculum 	<ul style="list-style-type: none"> –high degree of professional development of practitioners –high degree of support for practitioners –high degree of adaption of curriculum to practice –integration of several perspectives and constraints 	<ul style="list-style-type: none"> –high degree of correspondence of innovations to teachers’ beliefs about epistemology, teaching and learning –innovations solves problems of practitioners
Disadvantages	<ul style="list-style-type: none"> –strong long-term beliefs about epistemology, teaching and learning of teachers are in conflict with the innovation –low degree of support for practitioners –intended and enacted curriculum can differ strongly –rubber-stamping an innovation is intended, but not possible 	<ul style="list-style-type: none"> –innovations require a high degree of acceptance and skills among teachers who do not participate in the development of the innovation –local adaption possible, but general adaption difficult –dubious efficiency of innovation beyond project run-time of development phase of innovation 	<ul style="list-style-type: none"> –profound changes of teaching practice are hard to be implemented –usually low degree of integration of current research about teaching, learning and content of the related field

A third option is a bottom-up strategy, when teachers themselves design curricular innovations almost without any additional support. Although a high degree of correspondence of the innovation to their practice is assured, this strategy is suffering from a lack of wide implementation. Profound curricular changes are therefore hardly to be transposed. A lack of research-orientation might be a further problem, since research expertise is not

integrated explicitly. In fact it has to be emphasized that there is no implementation strategy without some disadvantages or pitfalls including the symbiotic approach. The latter basically suffers from the problem that the necessary professional development for teaching the innovation successfully is restricted to those teachers who are actively engaged in its development. Usually the amount of teachers involved in developmental arrangements based on symbiotic approaches is rather low. Thus, for each curricular innovation it has to be ensured how skills and relevant knowledge for teaching the innovation successfully will be transferred to those practitioners who are not involved in the developmental process

The HIPST project strategy

The HIPST project has decided for a symbiotic strategy for the development and implementation of case studies for teaching and learning with HPS about the NOS. The basic development is inspired by action research (McKernan, 2006) and participative action research (Eilks, Parchmann, Gräsel, & Ralle, 2004). Models rooted in action research are characterized by considering curricular innovations to be explored and developed within circles of retrospective understanding and future action. Ideas, concepts and strategies of teaching are planned, evaluated and reworked in cycles. A strong participation of teachers is characteristic for action research models, which therefore meet the needs of a symbiotic strategy of development and implementation. The model stresses the integration of different kinds of expertise into the developmental process in order to bring together separated communities of expertise. Researchers and teachers share ideas and perspectives and shape the developmental processes with their different kinds of expertise, knowledge and skills (Eilks, Parchmann, Gräsel & Ralle, 2004). Within HIPST researchers contribute with their knowledge about history and philosophy of science and students' preconceptions. They are responsible for structuring the developmental processes as well as for defining the key issues of each meeting of teachers and researchers. They organize accompanying research for evaluation and revision of the developed material. Teachers, on the other hand, contribute with their general didactic creativity, knowledge and skills based on their own teaching practice. They develop ideas and methods for teaching and learning, provide resources for evaluation and participate in accompanying research. Furthermore, the model ensures that teachers develop ownership of new teaching practices, which are specific for teaching HPS. Open discussions have to be moderated, negotiations among students have to be maintained and encouraged and activities, which are characteristic for the HIPST project, like open-ended inquiry and role-play have to be guided by the teachers.

For HIPST a double-cycle model has been chosen comprising the following systematic steps: A group of researchers and practitioners in the related field is constituted. They start their collaboration by sharing their ideas and perspectives. Researchers for instance follow the idea of developing case studies for teaching and learning about NOS with HPS. They put emphasis on avoiding to fall into the trap of a whiggish approach of history (e.g. Butterfield, 1931), which means that "history" is accused to interpret the past in terms of ideas of the present. One-dimensional stories of scientific success may be a consequence. Therefore, researchers in the project emphasize portraying science as a human endeavor bearing controversial and multifaceted ideas, concepts, theories and experimental cultures of science. On the other hand, science teachers stress that their lessons have to be adequate to the interests and capacities of their students. They define the scientific content and amount of teaching-time devoted to the considered HIPST-case study. During this phase researchers and practitioners start identifying obstacles and boundary conditions as well as options of the developmental process and capacities for evaluating the material in practice. Based on this preparatory work, the group decides for materials and case studies to be developed and explored during their future collaboration. Thereafter a second phase of developing the case study follows. Historical and epistemological issues have to be discussed and taken into account as well as didactical and methodological aspects of teaching and learning. A first evaluation of the case study follows guided by one or more teachers of the group. The tools of evaluation have to be adapted to the questions the whole group or the researchers have defined before. Based on a discussion of the results of the evaluation a reworking phase follows.

After a second test and evaluation the development of the case study will be terminated. During this second phase of evaluation it is highly desirable to invite further teachers to test the materials in order to figure out the needs of professional development for teachers, who have not been involved in the project before. Inviting further teachers from outside the project enables the group to learn more about how teachers use the materials offered to them. This procedure ensures that the material will finally be adapted in a way to support new teachers. Hence the developmental model avoids the typical pitfall of symbiotic strategies mentioned above. Due to the restricted run-time of the HIPST project of two years a two-cycle model is adequate even though a three-cycle model might be superior (Eilks, Parchmann, Gräsel, & Ralle, 2004). The process ends with a final configuration of the material and its translation into English. All case studies collected or developed within the HIPST project will be shared among the partners involved. Subsequently a choice of materials will be translated and published in national languages. Finally HIPST will provide a wide range of different case studies based on a HPS approach available in 8 different languages. The developmental model of the project based on a symbiotic implementation strategy ensures a high degree adaption to the community of science teachers without disregarding research results from educational research, history and philosophy of science.

The culture of teaching physics as an obstacle for implementing HPS

Recently the term of culture or subject-culture has been used for describing and understanding the stability of practices and beliefs among science teachers (Lüders, 2007, Willems, 2007). The term culture implies that its adherers share, keep and sustain common sets of constructions about reality (Müller-Roselius, 2007). A culture sustains itself by naturalizing systems of beliefs, opinions, judgments, routines and practices. Teachers as well as students share sets of expectations, behaviors and practices as perceivable signs of a related subject culture. The subjective side of culture is called the habitus of a given individual following the sociological perspective of Pierre Bourdieu. According to him the habitus of a person is at the same time an effect and a cause of the culture as it is. Among teachers of the same subject-culture the habitus is realized as a kind of kinship regarding practices, orientations and language. According to this perspective curricular innovations are the more in danger of failure the less they are in accordance with the current subject-culture. From the perspective of analyzing physics teaching as a culture the following issues are considered as relevant:

- the content which teachers regard as relevant for learning physics
- ways and styles of communication and interaction in the classroom
- norms and values held by teachers and students relevant for teaching and learning
- typical ways of running a lesson
- the general habitus of physics teachers
- general attitudes towards science of teachers and students
- beliefs about teaching, learning and classroom organization

A relatively well-known phenomenon is that physics teachers define their primary objective of teaching as conveying the truth about nature (Willems, 2007). In contrast to teaching English, physics teachers regard themselves as the ones who have to express and define knowledge clearly. Moreover, while during English classes different opinions do matter, the situation in physics classes is supposed to be different. Different opinions do matter less. As Osborne and Collins (2001: 454) indicated in an interview study with pupils, science is regarded as a subject with “less margin for error”. They follow that school science offers little to those pupils interested in expressing themselves. Moreover, as Williams pointed out, physics teachers believe their students want and are supposed to need clear guidance. They regard the content they have to teach as truth about nature, which they have to convey to their students as a collection of facts. This finding of a strong content-orientation has also been corroborated by further research (Markic, Valanides, & Eilks, 2006). The assumption that physics teachers tend to hold an epistemological belief about the transferability of knowledge to their students and a belief about classroom

organization as mainly teacher-centered has also been confirmed. As a consequence they do not understand content as a matter of discussion and negotiation among their students. A case study about a chemistry teacher (Tobin & McRobbie, 1997) found out that even when science is regarded as an evolving discipline the curriculum was enacted as memorizing facts. Therefore, memorizing scientific facts is an important aspect of teaching physics or even science along with a lack of teachers' competence for moderating discussions and negotiations among students (Driver, Newton & Osborne, 2000). Video-analysis of physics lessons has also shown that memorizing facts during physics lessons is actually more important than physics teachers themselves hold it to be the case (Reyer, Trendel & Fischer, 2004). According to the students' perspective science is essentially regarded as a body of knowledge characterized by facts, which have to be learned. But as a consequence science is compared to other subjects hardly appreciated as a creative endeavor (Osborne & Collins, 2001). The belief that science is lacking creativity has also been indicated for pre-service science teachers (Abell & Smith, 1992, Irez, 2006). Instead scientific knowledge is demonstrated in bits and pieces and is regarded by the pupils as something fragmented (Osborne & Collins, 2001). Accordingly scientific ideas appear as being given without providing opportunities to the students to develop deeper insights into the reasons for regarding a scientific assumption to be true. Moreover, a tendency of structuring lessons strongly has been indicated (Tesch & Duit, 2004). Thus, physics teachers usually have an orientation towards making their lessons run smoothly and according to a lesson plan. Even though they stress the importance of students being active during their lessons, they do not understand students' activities as active learning, but as being busy (Fischler, 2000). Differences among subject cultures even become evident in the design of rooms and spaces for teaching and learning (Willems, 2007). Even though physics classrooms, at least in Germany, are pretty well equipped with instruments for demonstrating physical phenomena, rooms for physics teaching are characterized by a teacher-centered culture. Students' desks and chairs are usually fixed and ordered in rows in front of the lecturing desk. The room disposition demarcates the teacher's own space for demonstrating experiments and physical phenomena from that of the students. Thus, the teacher's space is designed as a focal point of activities within the physics classroom. A culture of discussion and negotiation is hardly supported by such an arrangement. Rooms and spaces for teaching humanities instead are usually designed more flexible for allowing different forms of interaction like Willems (2007) demonstrates clearly by comparing the subject cultures of physics and German language. To sum up physics teaching is characterized as a culture of facts and contents which teachers are supposed to convey to their students. These findings are also mirrored by implicit assumptions of students toward science. They more easily associate physics (compared to English) with words referring to difficulty (than to ease), to males (than to females) and to heteronomy (than to self-realization) like Kessels, Rau and Hannover have shown (2006). Furthermore, students generally revealed a relative negative implicit attitude towards physics and they associated physics more readily with others than with words referring to themselves. The image of physical science comprises difficulty, masculinity and heteronomy. A general decline of students' positive attitudes is a well-known consequence (Hoffmann, Häußler, & Lehrke, 1998, Osborne, 2003, Reid & Skryabina, 2003, Sjöberg, 2000).

Learning about the NOS usually is at the very heart of HPS approaches. It is concerned with learning about process and context of science including transcendental-critical reflections on scientific knowledge as Litt (1959) has asked for. However, research has indicated that teaching and learning about NOS is not an explicit objective of science teachers (Lederman, 1999, Abd-el-Khalick, Bell & Lederman 1998, Mulhall & Gunstone, 2008). This is an important result, because if teachers will not value learning about the NOS as a central endeavor of their teaching, they hardly will choose an HPS based teaching approach. Several studies also have indicated that teachers' epistemological knowledge about science is hard to be transformed into an effective teaching practice for supporting students' learning about the NOS (Abd-El-Khalick, Bell, & Lederman, 1998, Abd-El-Khalick & Lederman, 2000, Hodson, 1993, Lederman & Zeidler, 1987, Akerson & Abd-El-Khalick, 2003). These results indicate further restrictions to an effective implementation of HPS. The reason might be that the teachers' pedagogical knowledge and pedagogical content knowledge (Loughran, Berry, & Mulhall, 2006) for an effective didactic use of HPS are not sufficient (Martins, 2007). It is also of great importance that teachers expect benefits from HPS for their own

teaching. Wang and Marsh (2002) have found out that teachers feel unsafe on how to use the history of science to enhance procedural understanding of science. Even though they appreciate the general benefit of this approach, they perceive the crucial benefit of the inclusion of history in contextual understanding. Clearly, teachers need further support for teaching about the nature of scientific knowledge and about processes in science with HPS approaches and for teaching about the NOS in general.

Obviously a single project like HIPST has a restricted power to initiate fundamental changes of subject cultures of physics, chemistry or biology like they are taught in schools. Nevertheless, several aspects of science teachers' professional development haven been taken into account for improving the situation towards the development of subject cultures, which are more open for an HPS approach. An overview of aspects taken into account by HIPST project is presented in table 2. The German HIPST group for instance strongly focuses on connecting different learning goals and achievements. Learning scientific content and about NOS have to be balanced in an ongoing process. Together with the teachers we as researchers discuss ways of making the NOS explicit in the classroom. The resulting case studies are tested in practice thereafter as prescribed by the developmental model of HIPST mentioned above. This process not only assures the enhancement of the quality of the case studies themselves, but also enables reflections of the teachers on their own practice of teaching.

Table 2: Comparisons of cultures of teaching physics and teaching HPS successfully as indicated by research.

History and philosophy in science teaching	The current culture of teaching physics
Physics is demonstrated as a process dependent on a wider cultural context, content counts as developed historically.	Physics is taught as truth and a collection of facts.
Students reflect on the nature of science explicitly.	Students do not reflect on the nature of science, teachers convey messages about NOS implicitly.
Science is demonstrated as tentative, a matter of negotiation and discourse among scientists. Students' conceptual change is supported.	Scientific content is not a matter of negotiation and discourse among students. Teachers provide scientific content. Spaces are designed for enabling teacher talk.
HPS encourages students to express their own ideas. Female role models are demonstrated.	Students associate physics with heteronomy. Physics is constructed as male.
Teachers have to focus on NOS as an explicit objective of their teaching.	Teachers do not focus on NOS as an explicit objective of their teaching.
Physics teachers' beliefs about classroom organization are progressive. They dispose of pedagogical content knowledge for moderating discussions and negotiations among students about a variety of concepts. They support students' meaning making, and transform reflected views of NOS during their teaching.	Physics teachers' beliefs about classroom organization, epistemological beliefs and beliefs about teaching objectives are likely to be traditional.
Teachers know how to use HPS to transform NOS into teaching practice.	Teachers do not transform NOS knowledge into a reflective teaching practice.
Teachers appreciate learning content, context and process of science with HPS.	If physics teachers appreciate history of science, they focus mainly on learning about context of science while feeling unsafe about teaching science as a process.

Conclusion

Major obstacles and boundary conditions for an effective implementation of HPS in science education have been analyzed in this paper. Based on the idea that teachers generally are the main responsible for curricular innovations, the HIPST project has integrated them in a central position. Within a symbiotic approach the project aims at the development of high quality case studies for teaching and learning science with HPS on the one hand and teachers' professional development on the other. Therefore, the project contributes to overcome some boundary conditions for teaching and learning science with HPS that have prevented this approach for being widely implemented although science educators have stressed benefits for decades. Among the products of HIPST are case studies, which are research based and evaluated in practice at the same time. They will provide a rich basis for further teacher training and curricular innovation beyond the runtime of the project.

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DEVELOPMENT OF A VALID AND RELIABLE PROTOCOL FOR THE ASSESSMENT OF EARLY CHILDHOOD STUDENTS' CONCEPTIONS OF NATURE OF SCIENCE AND SCIENTIFIC INQUIRY

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Abstract

Since the early 1960s, science education research is concerned with the development of assessment instruments concerning Nature of Science (NOS) and Scientific Inquiry (SI). Several instruments that have been devised from then on have to be criticized (see Lederman, Wade, & Bell, 1998). More recently, open ended instruments were developed in order to avoid weak points. Moreover, it is to note, that instruments with respect to SI were limited to students' ability to do inquiry with no attention given to what students understood about inquiry.

Concerning assessment with very young children (K-2), instruments have to face specific problems: children's reading and writing ability is not fully developed and the vocabulary used in the instrument has to be understood by the children. Consequently, more appropriate instruments are needed. This study introduces such a new oral protocol and scaling approach based on the VNOS-E (Lederman & Ko, 2003) and VOSI-E (Lederman & Ko, 2004). Face, content, and construct validity as well as interrater-agreement were investigated. The results show, that this approach is valid and applicable by various persons.

Introduction

Students' understandings of science and its processes beyond knowledge of scientific concepts have been emphasized in the current reform efforts in science education (AAAS, 1993; NRC, 1996; NSTA, 1989). In particular, the National Science Education Standards (1996) state that students should understand and be able to conduct a scientific investigation. The Benchmarks for Science Literacy (AAAS, 1993) advocates an in-depth understanding of scientific inquiry (SI) and the assumptions inherent to the process. Both reform documents consistently support the importance of students' possessing adequate understandings of nature of science (NOS). Research, however, has shown that teachers and students do not possess adequate views of NOS and SI that are consistent with those advocated in reform documents. Moreover, it is difficult for teachers to create classroom environments that help students develop adequate understandings of NOS and SI (Lederman, 1992; McComas, 1998; Minstrell & van Zee, 2000) without explicit instruction and assessment.

Nature of Science

NOS refers to the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). Although disagreements exist among philosophers of science, historians of science, scientists, and science educators regarding a universal definition for NOS, these disagreements are irrelevant to K-12 students (Abd-El-Khalick, Bell, & Lederman, 2000). It can be argued that the seven aspects of NOS referred to in the research literature are accessible to and relevant to K-12 students' everyday lives. It can further be argued that the aspects are at a level of generality that avoids any contentious arguments. The aspects of NOS referred to here involve an understanding that scientific knowledge is tentative, subjective, empirically based, socially embedded, and depends on human

imagination and creativity. Two additional aspects involve the distinction between observation and inference and the distinction between theories and laws. Being more specific to the age of students in this investigation (i.e., K-2), the aspects of nature of science of interest in this study are tentativeness, subjectivity, observation and inference, and empirical basis.

Scientific Inquiry

The NSES, (NRC, 1996) states that “Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries.” (p. 23) In addition to being able to conduct inquiries of various types, the NSES also promote students’ understanding about scientific inquiry (NRC, 2000). This understanding includes:

- knowledge about various methods of investigation (there is no single "scientific method"),
- understanding of the placement, design and interpretation of investigations within research agendas (current knowledge and direction guide investigations),
- recognition of assumptions involved in formulating and conducting scientific inquiries,
- recognition of limitations of data collection and analysis in addressing research questions,
- recognition and analysis of alternative explanations and models,
- understanding of the reasons behind the use of controls and variables in experiments,
- understanding of distinctions between data and evidence,
- understanding of relationships between evidence and explanations and the reliance on logically consistent arguments (based on historical and current scientific knowledge) to connect the two,
- understanding of the role of communication in the development and acceptance of scientific information

The history of the assessment of nature of science and scientific inquiry mirrors the changes that have occurred in both psychometrics and educational research design over the past few decades. The first formal assessments, beginning in the early 1960s, emphasized quantitative approaches, as was characteristic of the overwhelming majority of science education research investigations. Prior to the mid-1980s, with few exceptions, researchers were content to develop instruments that allowed for easily “graded” and quantified measures of individuals’ understandings. In some cases, standardized scores were derived. Within the context of the development of various instruments, some open ended questioning was involved in construction and validation of items. It should also be noted, that with respect to scientific inquiry, assessment was limited to students’ ability to do inquiry with no attention given to what students understood about inquiry.

More recently, emphasis has been placed on providing an expanded view of an individual’s beliefs regarding nature of science. In short, in an attempt to gain more in-depth understandings of students’ and teachers’ thinking educational researchers have resorted to the use of more open-ended probes and interviews. The same has been true with the more contemporary approaches to assessment related to nature of science.

A critical evaluation of assessment instruments has recently been provided elsewhere (Lederman, Wade, & Bell, 1998). Therefore, the purpose here is to summarize what is known about the assessment of understandings about nature of science and scientific inquiry.

Overall, there are two critical issues that have surrounded the “traditional” paper and pencil assessments of NOS: 1) assessment instruments are interpreted in a biased manner, and 2) some assessment instruments appear to be poorly constructed. These criticisms notwithstanding, it is interesting to note that research conclusions based on these instruments have been unusually uniform. That is, teachers and students generally score at levels considered to be less than adequate. Thus, although the various instruments suffer from specific weaknesses, if these were significant, it would seem improbable that the research conclusions would be so consistent. There is a more critical concern, however, about the “traditional” paper and pencil approach to the assessment of an individual’s understanding of NOS. Although not a new insight, Lederman and O’Malley’s (1990) investigation clearly highlighted the problem of paper and pencil assessments. They documented discrepancies between their own interpretations of students’ written responses and the interpretations that surfaced from actual interviews of the same students. This unexpected finding (i.e., the purpose of the interviews was to help validate the paper and pencil survey that was used) was quite timely, as it occurred when educational researchers were making a serious shift toward more qualitative, open ended approaches to assess individuals’ understanding of any concept. Although the VNOS-A was created to avoid some of the concerns about “traditional” assessments (as were the subsequent series of VNOS forms), the problem of researchers interpreting responses differently than intended by the respondent remains to this day. The problem exists at all age levels (K-adult), with increasing levels of uncertainty as the age of the respondent decreases. It is for this reason, that researchers should not abandon the interviewing of individuals about their written responses. Throughout the history of NOS assessment there has been a clear movement from traditional convergent assessments to more open-ended assessments. Most researchers realize how difficult it is to assess a construct as complex as NOS with multiple choice and Likert Scale items. However, interviews and open-ended assessments are time-consuming to conduct and score.

Rationale

The previous summary of assessment focused totally on nature of science. Quite simply, this is because no assessment instruments or protocols exist related to understandings about Scientific Inquiry.

Assessment Obstacles Specific to Very Young Students: The previously used assessment instruments are clearly problematic with respect to young children (grades K-2), for several reasons. Most obvious, is the inability of very young students to read and express their thoughts in writing in a coherent manner. There are also difficulties in simply reading the existing assessment probes to students. The developmental level of the vocabulary in these instruments is inappropriate for young students to understand and many of the examples used to illustrate several aspects of NOS and scientific inquiry are not familiar to many of these students. Consequently, more appropriate instruments are needed. The solution is clearly to use an oral administration of assessment instruments to small groups (e.g., five) of students and then record their answers. Interviewing students in small groups seems preferable given the problems with the dynamics of whole group discussions with young children. The diversity of responses is much greater for young children in small groups than during whole class discussion.

If we accept that young children are capable of developing understandings of nature of science and scientific inquiry and that young students should develop such understandings as part of the science curriculum a clear problem exists. There is a clear mismatch between the nature of existing paper and pencil instruments and the abilities and skills of very young children. Consequently, the purpose of this investigation was to develop a valid and reliable assessment protocol that can be used with very young students.

Science educators and teachers are becoming increasingly interested in young students’ understandings of nature of science and scientific inquiry. Few would disagree that such understandings are developed over an extended period of time. If students are to become knowledgeable by the time they graduate high school, attention to these educational outcomes should start as early as possible. Without valid and reliable assessment techniques teachers are unable to discern the effectiveness of their efforts. Hence, the significance of this investigation. The development of a valid and reliable assessment of nature of science and scientific inquiry for young learners will

serve to inform teachers and curriculum developers about student understandings and the success of their instructional approaches. Such data will also enable teachers and curriculum developers to produce more targeted and effective materials for young learners.

From a research perspective, this investigation will provide researchers with access to students' understandings at an age level not known before. In addition, the assessment developed here will allow for the collection of data on the development of young students' understandings of nature of science and scientific inquiry and will allow, for the first time, a coherent connection of data across K-12 grade levels. In the end, this research data serves to inform the practical concerns of teachers and curriculum developers. At the most ambitious level, the results of this investigation provides all those concerned with nature of science and scientific inquiry as educational outcomes with a data base that has been unavailable before and a mechanism to further enrich the data available. In short, the proposed investigation will contribute significantly to the achievement of current educational reforms in science education.

Methods

The impetus for this investigation came from problems with assessing the understandings of K-2 students during a multi-year professional development program stressing inquiry, context, and nature of science (i.e., Project ICAN). Previously validated instruments VNOS-E (Lederman & Ko, 2003) and VOSI-E (Lederman & Ko, 2004) were not usable with young students because these students could not read or coherently express themselves orally in response to the questions on these instruments. During the past two years, a concerted effort to revise these instruments into an oral protocol and scoring approach that could be used to provide data on young students' understandings was pursued.

Face validity: A focus group of six teachers of K-2 students was formed to revise the language used on the aforementioned instruments into a form that would be readily understood by K-2 students. The revised assessment items were informally used with groups of 5-7 K-2 students to establish whether the language was understandable. To date, the items appear to be understandable and developmentally appropriate.

Content validity: It is one thing for assessment items to be understood, but it is another to establish that the items are actually assessing what they are purporting to assess. A group of five science educators, well-versed in the aspects of nature of science and scientific inquiry of interest, were asked to evaluate each of the assessment items. In particular, each science educator was provided with a list of the assessment items and the specific aspect of nature of science and/or scientific inquiry targeted by each item. The five individuals evaluated each item and a level of agreement of 80% was used as a minimum criterion. Any item falling below an 80% level was revised and re-submitted to the panel of science educators until all items achieved the necessary level of agreement.

Construct validity: It is possible that an expert panel can agree on what items are assessing, but stronger evidence for validity can be established if individuals believed to differ in understanding of the constructs (i.e., nature of science and scientific inquiry) actually score differently on the assessment. A group of kindergarten students (n=18) were taught about nature of science and scientific inquiry over a three-month period, using techniques already established as effective in previous research, and these students' scores on the assessment items were compared with their pre-test scores as well as with three comparable groups of students (i.e, students spanning K-2). The desired result was that those students taught nature of science and scientific inquiry would score significantly better than those students who were not taught this content. In short, this approach would support the assumption that the developed instrument would distinguish between those students understanding the constructs of concern with those who did not have such understandings

Inter-rater agreement (reliability): Given that the assessment developed is an oral protocol with students' open responses recorded and then scored, reliability could only be established by assessing the consistency of scoring by independent raters. Consequently, the consistency established is more accurately described as inter-rater agreement

than reliability. A group of five elementary teachers were trained in the scoring of students' responses relative to the constructs of scientific inquiry and nature of science. The individuals selected as raters were teachers with a demonstrated understanding of the constructs. Hence, the primary effort of the researcher was in preparing individuals to use the scoring rubric and not to teach the raters about nature of science or scientific inquiry. All five raters were asked to independently score the same set of student responses. The raters' scores were compared to the scores derived by the researcher, who in this case is considered the reference standard. An agreement level of 80% was sought. Raters were asked to score responses from a purposefully selected set of three students. One student who exhibits a good understanding, one with a moderate understanding, and one with a low level of understanding. This approach enabled the researcher to assess whether inter-rater agreement is independent of the level of understanding exhibited by student responses.

Results

The results are organized and reported relative to the various aspects of validity and reliability discussed in the previous section.

Face validity: A focus group of six elementary teachers, who previously illustrated adequate understandings of scientific inquiry and nature of science were asked to review the assessment items. The teachers were asked to comment on the development appropriateness of the questions as well as their students' ability to understand the language used in the assessment items. Items were revised until there was 100% agreement among the teachers that the questions would be appropriate for K-2 level students. These assessment items were then presented to three focus groups of K-2 students. A focus group of 5-7 students was formed for each of the grade levels. Students were asked the following questions with respect to each of the assessment items:

- In your own words, explain what the question is asking you about science
- Are there any words that are difficult to understand?
- How can the question be changed so that your classmates will understand the question more easily?

The grade 2 focus group was asked to comment on the questions first. After revisions were made, the same process was followed with the grade 1 students followed by the kindergarten students. At each stage, 100% agreement was reached with all students in each focus group. After questions were sequentially revised, they were again given to the six elementary teachers for review. The teachers had no disagreements with the revisions that were made based on students' comments. If anything, the teachers were pleasantly surprised by the insights of the students and were further convinced that students could understand the questions being asked. It was concluded that the final set of questions had achieved face validity. The set of questions included in the final assessment instrument are presented in Appendix A.

Content Validity: A group of five science educators, well-versed in the aspects of nature of science and scientific inquiry of interest, were asked to evaluate each of the assessment items. In particular, each science educator was provided with a list of the assessment items and the specific aspect of nature of science and/or scientific inquiry targeted by each item. The five individuals evaluated each item and a level of agreement of 80% was used as a minimum criterion. Any item falling below an 80% level was revised and re-submitted to the panel of science educators until all items achieved the necessary level of agreement. A level of 100% agreement was reached for each of the assessment items on the first round of feedback. These data were taken as support for the content validity of the assessment items.

Construct Validity: Further evidence for validity of the assessment items was based on the logic that students understanding nature of science and scientific inquiry should score differently than students that has no knowledge of these topics or had no opportunity to learn about nature of science or scientific inquiry.

A group of kindergarten students (n = 14) were taught about nature of science and scientific inquiry over a three-month period, using the explicit, reflective techniques already established as effective in previous research. These students' scores on the assessment items were compared with their pre-test scores as well as with three comparable groups of students (i.e, students spanning K-2, n = 64). Students were asked questions orally in groups of 3-4, but data were collected on each student's understandings). Table 1 shows the frequencies of students with adequate understanding and percentage for these two groups. Moreover, pretest and posttest results are shown for the group of students that was taught about NOS and SI (intervention group).

Table 1. Frequencies of students with adequate understanding and percentage.

Aspect of NOS/SI	Pretest Intervention Group (n=14)	Controll Group (n=64)	Posttest Intervention Group (n=14)
Tentativeness	9, 64.3%	47, 73.4%	12, 85.7%
Subjectivity	7, 50%	33, 51.6%	11, 78.6%
Observation vs. Inference	2, 14.3%	22, 34%	12, 85.7%
Empirical Basis of Science	3, 21.4%	19, 29.7%	11, 78.6%
All Investigations Begin with a Question	0, 0%	0, 0%	13, 92.9%
Scientists Collect Empirical Data to Answer their Question	4, 28.6%	21, 32.8%	11, 78.6%
Data and Prior Knowledge are Used to Answer Questions	0, 0%	14, 21.8%	8, 57.1%
There is no Single Scientific Method	10, 71.4%	41, 64.1%	13, 92.9%

The pretest data for kindergarten students and data for the K-2 comparable groups are not surprising in that the results are similar to the understandings documented for older students (Abd-El-Khalick & Lederman, 2000; Lederman, 1992). It is important to note that the results can only be compared with the literature on older students because there is no existing literature on students' understandings of nature of science and scientific inquiry for students at K-2 levels). Of most importance here are the posttest data for the kindergarten students who were taught nature of science and scientific inquiry. Consistent with the literature, these students improve dramatically in their understandings in response to an explicit, reflective instructional approach. In terms of the development of a valid assessment protocol, the data indicate that the assessment approach distinguishes between students who understand nature of science and scientific inquiry. That is, the students who had an opportunity to learn the constructs in question performed better than students who did not have any opportunity to learn nature of science or scientific inquiry. Consequently, the assessment protocol was assumed to have construct validity.

Inter-rater agreement (reliability): Given that the assessment developed is an oral protocol with students' open responses recorded and then scored, reliability could only be established by assessing the consistency of scoring by independent raters. Consequently, the consistency established is more accurately described as inter-rater agreement than reliability. A group of five elementary teachers were trained in the scoring of students' responses relative to the constructs of scientific inquiry and nature of science. The individuals selected as raters were teachers with a demonstrated understanding of the constructs. Hence, the primary effort of the researcher was in preparing individuals to use the scoring rubric and not to teach the raters about nature of science or scientific inquiry. All five raters were asked to independently score the same set of student responses. The raters' scores were compared to the scores derived by the researcher, who in this case is considered the reference standard. For each assessment item, levels of agreement were 80-100%.

The purpose of this aspect of assessment development was to determine if other individuals could use the protocol in a consistent manner. If such were not the case, the assessment protocol would be of little use to teachers and/or researchers. The data clearly indicate that inter-rater agreement (reliability) was obtained for assessment protocol. Certainly, more research is needed to see if consistency can be achieved for larger numbers of teachers or researchers.

Conclusions and Implications

Science educators and teachers are becoming increasingly interested in young students' understandings of nature of science and scientific inquiry. Few would disagree that such understandings are developed over an extended period of time. If students are to become knowledgeable by the time they graduate high school, attention to these educational outcomes should start as early as possible. Without valid and reliable assessment techniques teachers are unable to discern the effectiveness of their efforts. Hence, the significance of this investigation. The development of a valid and reliable assessment of nature of science and scientific inquiry for young learners serves to inform teachers and curriculum developers about student understandings and the success of their instructional approaches. Such data will also enable teachers and curriculum developers to produce more targeted and effective materials for young learners.

From a research perspective, this investigation provides researchers with access to students' understandings at an age level not known before. In addition, the assessment developed here allows for the collection of data on the development of young students' understandings of nature of science and scientific inquiry and allows, for the first time, a coherent connection of data across K-12 grade levels. In the end, this research data serve to inform the practical concerns of teachers and curriculum developers. At the most ambitious level, the results of this investigation provide all those concerned with nature of science and scientific inquiry as educational outcomes with a data base that has been unavailable before and a mechanism to further enrich the data available. In short, the proposed investigation contributes significantly to the achievement of current educational reforms in science education.

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Appendix A

Young Children's Views of Science

Name: _____

Grade Level: _____

Date: _____

Instructions for a teacher / a researcher

- This questionnaire is designed for students who have limited reading and writing abilities.
- It is best to interview a small number of students (3-4) at a time. It is also recommended that the interviews take place during two meeting periods of 30-45 minutes each.
- Please record students' responses to each question with notes and audio-taping.
- Remind the students that there are no "right" or "wrong" answers to the following questions.

PART I.

[This first set of questions is used to establish that the child has some knowledge of what Science is as opposed to other disciplines so that when their opinions are asked during the rest of the interview the interviewer has faith that the child is referring to science. They also serve to establish a conversational rapport with the students. Disregard the rest of a child's responses if it becomes clear that the child's opinions are about something they clearly have no knowledge about. If you are conducting these interviews over a two day period then you can choose to not involve these students in the second part]

Can you tell me something you know about science?

Do you ever learn about science in school?

Can you tell me what you learned?

Have you ever learned about science somewhere else other than school? Where? What did you do?

How is science different from other things you learn about?

You have been telling me many things about science.

So, "What is Science?"

What is a Scientist?

What do they **Do**?

How do they do their work?

Have you ever seen a scientist?

Do you know one?

What do they do?

PART II.

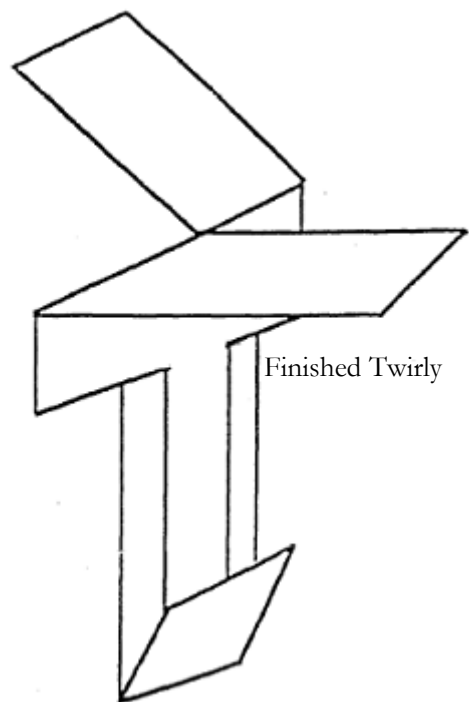
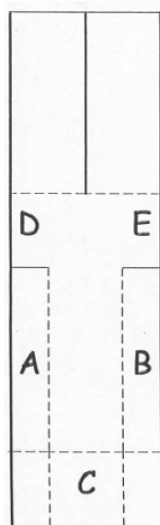
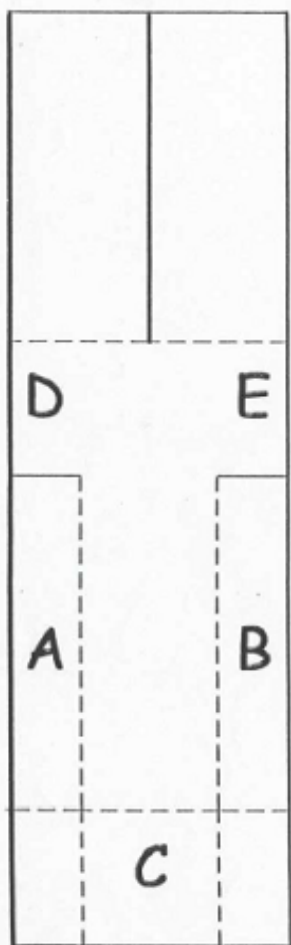
1. Tell the students that you are going to show them something and that you want them to watch very carefully. Drop the two different size paper helicopters one at a time (see attachment). Ask each child to make one observation and then one inference about what they just saw. Then ask: Was what you just watched a scientific investigation? Why? Why not? If they say it wasn't, ask them what they would need to do to make it into an investigation.
2. There was a woman who loved birds. She traveled around the world to study them. As she traveled she noticed that birds had many differently shaped beaks. For example, some were long and thin, some were big and sharp, and some were tiny and short. She also observed that birds ate different types of food. She asked the question, "Is there a connection between birds' beak shapes and the types of food they ate?"
 - (a) Do you think she was working like a scientist? Why or why not?
 - (b) Do you think her work was an experiment? Why or why not?
 - (c) What should she do next to answer her question?

3. How many of you know something about Dinosaurs? (Students will immediately start telling you everything they know about Dinosaurs...you can get some control of the discussion by saying: Each of you tell me **one** thing you know about dinosaurs...then go on to ask the following questions)
- (a) How do scientists know that dinosaurs really lived since there are no dinosaurs around anymore and no one has ever seen them?
 - (b) What do scientists think dinosaurs looked like? Why do scientists think they look this way?
 - (c) Scientists don't always agree on the reasons about what happened to make the dinosaurs all die away. Why do you think they don't agree?
 - (d) If your friend said that he knew the reason for what happened to the dinosaurs, what would he have to do to make scientists believe him? Why?
- [Alternative Question: If the students are too distracted by the dinosaur question then you might choose to use this one instead:]
- How do the people who predict the weather on TV use science?
How do they decide what the weather will be today?
Weather reporters don't always agree with each about the weather? Why do you think they disagree?
4. You have all told me know about a lot of different facts and ideas about science.
- (a) Do you think scientists will change their minds about these same science facts years from now? Why?
 - (b) Can you give me an example of some science idea that might change in the future?
5. Do you think that scientists are creative when they do their work? Can you give me an example? When do you think they are creative when they are doing an investigation?

Directions for paper helicopters used with question #1

<Twirlies>

- 1. Cut out the pattern, cutting along all solid line.
- 2. Fold "A" inward.
- 3. Fold "B" inward.
- 4. Fold "C" upward
- 5. Fold "D" backward.
- 6. Fold "E" forward.
- 7. Hold with flaps up and drop from a high place.



ARE HISTORICAL CONTEXTS SUITABLE FOR ASSESSING STUDENTS' COMPETENCES IN THE FIELD OF NATURE OF SCIENCE AND SCIENTIFIC INQUIRY?

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Abstract

Regarding assessment in the field of Nature of Science (NOS) and Scientific Inquiry (SI) there is a lack of valid large-scale instruments (see Lederman, 2007). This study aims at developing a large-scale instrument assessing students' competences concerning NOS and SI. Competence is seen as students' cognitive ability to apply their knowledge in various contexts. Lederman (2006) points out eight aspects of NOS students can reasonably be expected to know about. National Science Education Standards (NRC, 2000) provide such aspects concerning Knowledge about Scientific Inquiry, respectively. These two ideas build up the basic content of this study. In terms of competences, not only the knowledge, but also the non scientific context plays an important role. This paper concerns with the question if historical case studies can be enlisted to build up appropriate contexts for test items. A first study with 9 items relating to three contexts and students from Germany (N=225) and the United States (N=63) showed no significant effect of the context on difficulty. A second study with 107 items related to 13 contexts and students from Germany (N=1080) did not show significant effects either. Thus, it can be concluded that historical contexts are appropriate for that test development.

Introduction

Nature of Science (NOS) and Scientific Inquiry (SI) have been of interest in science education for long time (for a full overview see Lederman, 2007). Beside the work in specifying these topics (e.g. by McComas, Clough, & Almazora, 1998, Osborne, Collins, Ratchiffe, Millar, & Duschl, 2002, Lederman, 2006, NRC, 1996) or in designing material for their implementation in school (e.g., Carey, Evans, Honda, Jay, and Unger, 1989, or, Lederman, & Abd-El Khalick, 1998) assessment related to NOS and SI is a large field of research: Lederman (2007) discusses various approaches on assessing students' and teachers' conceptions starting with research of more than 50 years ago.

When designing an assessment instrument for NOS and SI, firstly, one has to outline what is meant by NOS and SI. There are different attempts to find a description of the field of interest, such as comparing international education standard documents (McComas et al., 1998) or conducting a Delphi Study (Osborne et al., 2002). However, Lederman (2006) observes that “no consensus presently exists among philosophers of science, historians of science, scientists, and science educators on a specific definition for NOS” (p. 303). Lederman, Abd-El Khalick, Bell, and Schwartz (2002) point out that many of these disagreements “are irrelevant to K–12 instruction” (p. 499). Instead of providing a single definition of NOS, they therefore suggest focusing on aspects relevant for a student’s daily life. Therefore, they propose seven aspects characterizing the Nature of Scientific Knowledge: “scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a universal recipe-like method for doing science, and the functions of and relationships between scientific theories and laws” (p. 499). These aspects are not controversial and agreed upon by everyone. Moreover, they distinguish NOS from the Nature of Scientific Inquiry (SI). Even if these topics are closely related their focuses is different: while NOS focuses on scientific knowledge, SI focuses on scientific processes. SI itself covers two different perspectives (cf. NRC, 1996). On the one hand, it stands for the ability to do SI in terms of process skills. On the other hand, it stands for knowing about SI and understanding it. Both perspectives have to be seen as opposed and require fundamentally different assessment instruments. Lederman (2007) mentions that many instruments concerning NOS are criticized on validity issues. However, with focusing on the seven aspects mentioned above Lederman et al (2002) faced this problem and were able to provide a valid questionnaire concerning students’ views on NOS.

Even if there is no consensus about a specific definition, there obviously is a consensus about the necessity of NOS and SI as educational goals. For example, Driver, Leach, Millar, and Scott (1996) provide five arguments why NOS should be taught in school. Concerning scientific literacy, Bybee (1997) presents a framework of scientific literacy that also contains aspects of NOS and SI. Thus, it seems quite obvious that these topics are mentioned in international science education standard documents (e.g., AAAS, 1993; NRC, 1996; Council of Ministers of Education, 1996; Department of Education and Science, 1989; KMK, 2005; for an exemplary overview see also McComas, and Olson, 1998).

Like some other European countries, Germany passed educational standards on science based on the concept of competences. In this context, competence means cognitive abilities and skills that enable problem solving in various situations (Weinert, 2001). Thus, the German standards cover mainly higher cognitive skills, and some practical performance skills related to scientific inquiry. Due to the introduction of these standards and due to Programme for International Student Assessment (PISA) assessing scientific literacy the term competence has come into focus of educational research.

When talking about standards and teaching goals it is also important to think of how to assess them and how to diagnose students. Related to the evaluated sample instruments have to be designed differently: e.g., instruments administered in science classes in school will have to prove individual measures as precise as possible in order support or to judge students. In contrast, when thinking of evaluating standards nationwide’ large-scales instruments become much more important which measure on class and school level. This paper relates to the latter type of instruments and combines the two fields of research mentioned above: on the one hand, NOS and SI, and on the other hand competences. In doing so, it is concerned with the development of a multiple-choice paper and pencil test assessing students’ competences in the field of NOS and SI.

Rationale

Concerning assessment in the field of NOS and SI, one important and often cited instrument is the *Views of Nature of Science Questionnaire* (VNOS, Lederman et al. 2002). This questionnaire “aims to elucidate learners’ NOS views and generate profiles of the meanings they ascribe to various NOS aspects” (Lederman et al., 2002, 517). It

consists of open ended questions and can be used in order to get detailed insight in students' conceptions of NOS. While conceptions of NOS and SI focus on traits competences are expressed by students' performance by addressing cognitive skills or practical skills. In this context, competences can be understood as students' abilities to apply their knowledge of NOS and SI to new situations. Thus, one has to outline the **knowledge** which is necessary to solve the task, and the **situations** (or **contexts**) in which it has to be applied.

Concerning the **knowledge**, this study uses the aspects characterizing the nature of scientific knowledge proposed by Lederman et al. (2002), further named as Nature of Scientific Knowledge (NOS). Accordingly, aspects characterizing scientific inquiry as lined out by the NRC (2000) are used, further named as Nature of Scientific Inquiry (NOSI). These aspects are reasonably to be known by K-12 students. Each set of aspects is concentrated to three core aspects (see table 1). These six core aspects span the knowledge that students have to apply in specific contexts. In order to define the **context**, students have to deal with, the authors wondered about ways of addressing NOS and NOSI in school. One widely spread approach is the use of historical examples as suggested by, e.g., McComas (2008). By reflecting about such cases of science history, aspects of NOS and NOSI can be analyzed and discussed.

Table 1. Core aspects of Nature of Scientific Knowledge and Nature of Scientific Inquiry.

	NOS	NOSI
Core aspects	Scientific knowledge...	Scientific investigations...
	... is tentative	... begin with a question
	... is subjective	... embrace multiple methods and approaches
	... is empirically based and inferential	... allow multiple interpretations

In order to design a paper and pencil competence test in the field of NOS and SI, the idea of using historical cases for implying NOS and SI was employed in item development. Items' difficulty is compared to the context addressed in an item to investigate, if this transfer is suitable.

Methods

In a first study, nine multiple choice items were designed for three different contexts from physics history: *The discovery of the neutron*, *The vacuum*, and *The planetary system* (three items per context). Item development is based on a model devised according to the findings of Kauertz and Fischer (2006), who could identify factors that determine an item's difficulty within a test on physics subject matter. The nine items are focused on the core aspects of NOS and NOSI as mentioned above. Within one context, a narrative on the historical case was provided. The items then required the student to analyze this narrative from the viewpoint of NOS or NOSI, respectively. Five answer options were given, and it was indicated that only one of them is correct. The nine items were administered to n = 225 German and n=63 U.S. students. Students were 14 to 17 year old, and had taken physics courses at least in the school year before data collection. All performance levels were represented in this sample.

The first study was run in order to find out if students can handle this sort of items at all. Thus, each item was supplemented by a short questionnaire on the comprehensibility of the item (AAAS, 2007, 4). Within this questionnaire, the students were asked to circle any word in the item they are unfamiliar with, or they do not know. Moreover, they were asked to give a reason for their choice and to indicate if they had guessed when answering the question.

Since no specific difficulties could be identified (see details in section "Results"), 107 items were developed following the same principle as in the first study. However, only four options were given instead of five. These 107 items covered 13 different historical stories addressing various physics topics. For this second study, the items were administered to n=1080 15-16 year old German students. Again, all performance levels were represented in this sample, and the students had taken physics courses at least in the school year before data collection. A multi-matrix

design was applied to assure that each item was processed at least by 100 students: the 107 items were assorted to 24 booklets so that each booklet contained about 13 to 16 items. Between each two booklets there was an item overlap of about two third. Net processing time for each booklet came to 30 minutes.

Results

First study

A unidimensional Rasch-model was fit to the data using Ministeps. Person reliability was 0.98, and item reliability 0.47. This low item reliability is probably due to the low amount of items. Comparing the German and the U.S. subsample descriptively, similar answer patterns can be found. Figure 1 exemplarily shows the percentage of students checking an answer option within item 1 of the context *The discovery of the neutron*. The correct answer (option 1) was checked by a comparable amount of students in both countries while the attractiveness of option 3 and 4 differs. Similar patterns are found for all of the nine items. Comparing the mean ability of German students ($M=0.21$, $SE=0.078$) and U.S. students ($M=-0.09$, $SE=0.13$) no significant difference could be found, $t(286)=1.82$, $p=0.07$, $r=0.11$ so far.

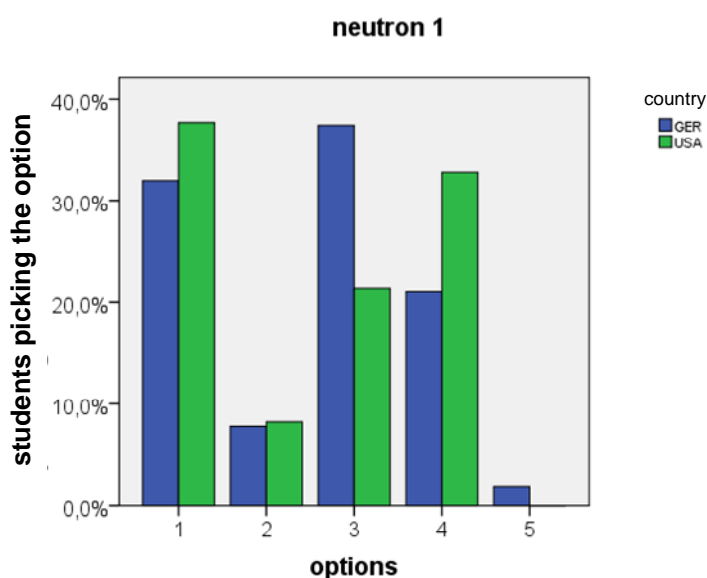


Figure 1. Pattern of answering on one item of the context "The discovery of the neutron".

Table 2 shows the estimated item difficulties. At first appearance, item difficulty is independent from the context. A Kruskal-Wallis-test supports this result: there was no significant effect of context on item difficulty, $H(2)=0.622$, $p=0.733$. In addition, the very right column lists the percentage of students who indicated that they had guessed when they answered the item. One would expect that this percentage increases with increasing item difficulty. The correlation between the estimated difficulty of an item and the percentage of students indicating that they had guessed when answering is $r=.77$ ($p>.05$). This value supports our expectation, however, it has to be handled carefully due to the small amount of items ($n=9$).

In summary, this first study showed that the items are applicable to German and U.S. samples. Moreover, the context had no influence on item difficulty as expected. Thus, this idea of item development basing on cases of physics history could be used for further item development. To improve some of the nine items already developed students' information on the words they were unfamiliar with and the reasons why they checked a specific answer were used. Thus, the texts were kept as simple and comprehensible as possible. Moreover, some reasons indicated by the students could be used to improve the distracters. Finally, the most unattractive option was taken out and the number of options was reduced to four.

Table 2. Estimated difficulties of each item.

Context	Item	Estimated difficulty	% of uncertain students
The discovery of the neutron	1	0.94	45.6
	2	0.00	46.7
	3	-1.55	21.3
The planetary system	1	0.20	29.4
	2	0.25	48.7
	3	0.18	38.9
The vacuum	1	-0.19	42.6
	2	1.31	46.2
	3	-1.14	29.6

Second study

107 items were used for this study; however, one item was neglected for the analysis, since its historical soundness has been put into question. As in the first study, a unidimensional Rasch-model was fit to the data. However, Conquest was used since Ministeps is unable to calculate on that number of items. Weighted mean square (WMNSQ) was seen as an indicator if an item is fitting the model. Based on the limits $WMNSQ \in [0.8; 1.2]$ there was no item with a bad fit. EAP/PV reliability was estimated with 0.593. Figure 2 shows the distributions of person abilities and item difficulties. From this figure, the reason for that low reliability can be seen easily: the distribution of person abilities ($M_{pers}=0.83$, $SD_{pers}=0.98$) is shifted against the distribution of item difficulties ($M_{it}=0.00$, $SD_{it}=0.93$). This means that the items are too easy for the investigated sample. This also means that the items are not measuring students' abilities with a high resolution, which again leads to a low reliability. However, these results are good enough in order to investigate the question of the context, as done in the first study. The items under investigation were assigned to 13 different contexts from physics history. Using an ANOVA no significant effect of context on item difficulty could be found, $F(12, 93)=1.022$, $p=0.436$. This supports the findings of the first study.

Conclusions and Implications

The study was aimed at showing if cases of physics history are suitable for developing multiple-choice test items in the field of NOS and NOSI. This question was approached by developing test items, which contained a narrative based on a historical case (context) and required the student to reflect on this case from a NOS perspective or NOSI perspective, respectively. Within a first study, no specific difficulties for students when solving the items could be identified. Moreover, this study indicated that there is no significant influence of context on item difficulty. Additionally, the items were appropriate for an international sample. In a second study a higher amount of items and students were investigated. The items were found to be too easy. Concerning the question of context, this results of this study supported the findings of the first study, however. In summary, both studies showed that using historical contexts is appropriate for developing test items in the field of NOS and NOSI.

Even if this study indicates that the basic idea of using historical contexts for test development is appropriate in principle, there are some restrictions that have to be worked on in future. One limitation is the low person reliability. Moreover, the items of the second study have only been used in a German sample with a domination of students from Gymnasium, a type of school that is done by mostly high performing students. After item improvement, a further study will contain another data collection in Germany as well as in the United States considering the whole range of performance. Having this international sample, reliability can be calculated again. Another limitation refers to the question of validity. This question will be approached by further correlation analyses comparing the developed items with cognitive abilities, reading comprehension, interest in physics, and views on NOS, respectively. This allows differentiating between these influences and competence in the field of NOS and SI.

In summary, this study shows a first step on the way to a paper and pencil instrument assessing competences in the field of NOS and NOSI. Further studies and analyses will lead to an instrument that can be applied to large samples. Moreover, this instrument will allow further investigations of the structure of competence in the field of NOS and NOSI as well as a deeper investigation of the relation between NOS and NOSI.

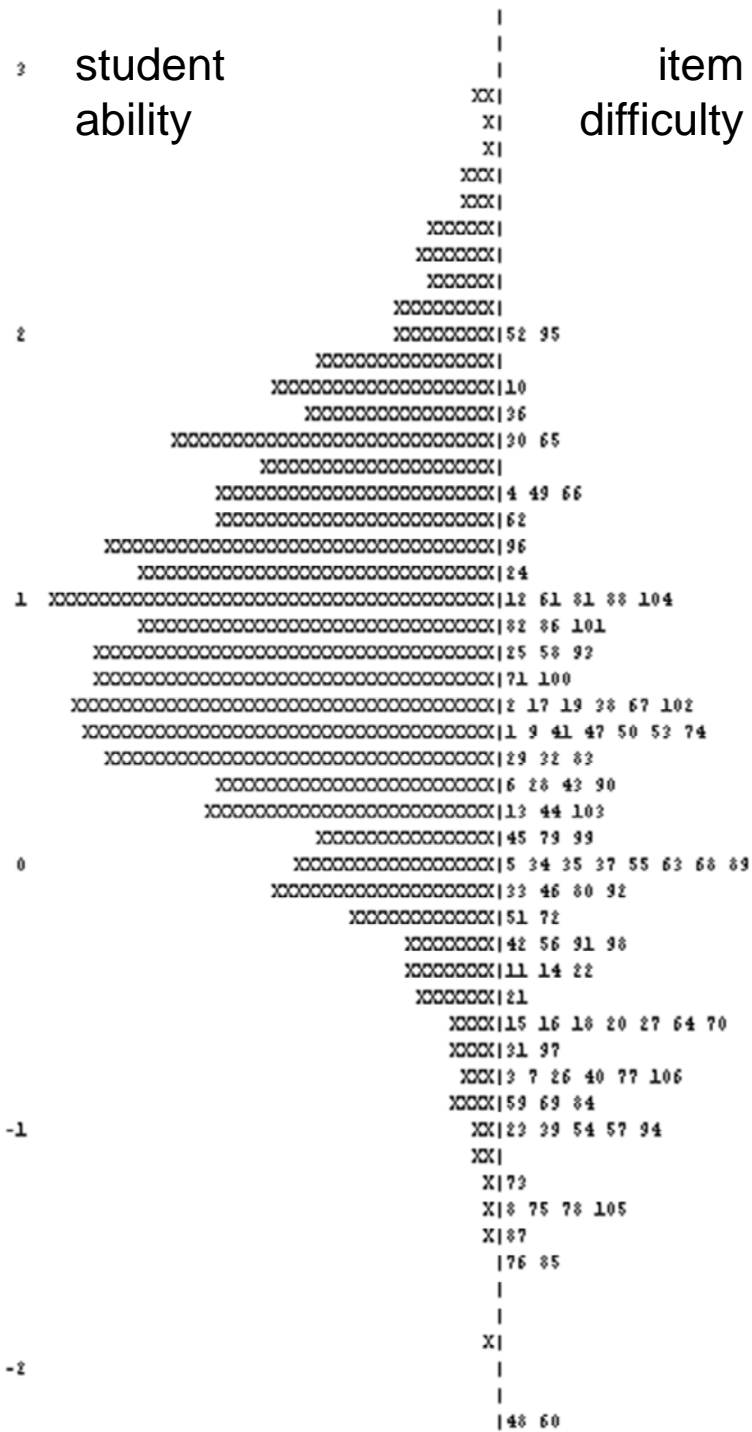


Figure 2. Distributions of student ability and item difficulty. Each x represents 1.6 students. Each number indicate one item.

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EXPLORING COMPETENCIES IN UNDERSTANDING THE NATURE OF SCIENCE AND SCIENTIFIC INQUIRY

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Abstract

Informed understandings of the nature of science (NOS) and scientific inquiry are generally accepted goals of science education and deeply anchored in national science education standards since many years. This study illuminates the central features of scientific inquiry and the nature of science and focuses on the assessment of inquiry competencies and their relation to beliefs on the nature of science. Rasch modeling of students' inquiry competencies was performed with a large sample of 1553 secondary school students. Final analyses on the relation to NOS beliefs were conducted with 218 participants who were in seventh ($n = 50$), eighth ($n = 58$) and ninth ($n = 110$) grade. Students in higher grades showed more advanced inquiry and NOS competencies. Different dimensions of inquiry skills and NOS beliefs correlated positively on a medium level. Besides science experience and prior achievement, NOS beliefs contributed to the formation of inquiry skills. The findings are discussed with respect to implications for science teaching and student assessment.

Introduction

Understanding the underpinnings of scientific knowledge is regarded as an important prerequisite to cope with the demands of modern society. That is why informed understandings of the nature of science (NOS) and scientific inquiry are generally accepted goals of science education and deeply anchored in national science education standards since many years (AAAS, 1990; NRC, 1996; QCA, 1999).

Conceptions of scientific inquiry and the nature of science are intensively discussed in science education policy documents as well as research literature and thereby often conflated. Although both aspects of science certainly interact and overlap, they can be distinguished from each other. Scientific inquiry, on the one hand, refers to the processes and activities of science, like questioning, hypothesizing or planning investigation. Nature of science, on the other hand, refers to the epistemological assumptions underlying these scientific processes and the consequences of these assumptions to the nature of scientific knowledge. As such, realizing which questions can be solved by science and knowing that hypothesizing involves human creativity and imagination reflects an adequate understanding of the nature of science (Lederman et al., 2002).

Scientific inquiry implies the use of scientific process skills like observing, questioning, hypothesizing, or analyzing data and the combination of these with scientific reasoning to develop scientific knowledge (Klahr & Dunbar, 1988; Lederman et al., 2002; Roberts & Gott, 1999; Schauble, Glaser, Duschl, Schulze, & John, 1995). Usually, the term scientific inquiry encompasses two aspects: (1) doing scientific inquiry, i.e. practical lab-work activities, and (2) understanding about scientific inquiry, i.e. the accompanying cognitive reasoning processes that make sense of the procedures and indicate students' deepened understanding of the investigation (Abd-El-Khalick et al., 2004). In this study and corresponding to the German national standards, scientific inquiry is regarded as a cognitive problem-solving process dealing with problems and phenomena from the natural world (Klahr & Dunbar, 1988; KMK, 2005; Mayer, 2007). A problem-solving process can be specified as a sequence of sections that fit together depending on the type of problem to be solved (Klieme, Funke, Leutner, Reimann, & Wirth, 2001). The sequence consists of the internal representation of the problem, development of a way to solution, application of an adequate solution method and evaluation of the results. Competence in scientific inquiry is then characterized by the following four cognitive process skills (Mayer et al., 2009): *Formulating scientific questions* and *generating hypotheses* as a way to internal representation of the problem, *planning investigation* to develop a way to solution, and *interpreting data* to evaluate the results of the problem-solving process. In order to characterize students' educational outcomes in terms of cognitive competence, the mentioned problem-solving skills are regarded as detached from practical lab-work, solely at a cognitive level. Thereby, students' competence to understand scientific inquiry (Abd-El-Khalick et al., 2004) and to make use of an analytical and rational worldview is emphasized (KMK, 2005).

The nature of science is characterized by a not precisely defined bundle of aspects related to scientific knowledge and knowing. It is agreed upon that scientific knowledge is subject to change, is based on and derived from observations of the natural world, is to some extent subjective, necessarily involves human inference, relies on the invention of explanations, and is socially and culturally embedded (Lederman et al., 2002). To some degree, parallels exist between research on the nature of science and investigations on epistemological beliefs in science (Conley, Pintrich, Vekiri, & Harrison, 2004; Elder, 2002). Therefore, five NOS dimensions are addressed in this study that build on the theoretical conceptions on the nature of science (McComas & Olson, 1998; Osborne et al., 2003; Lederman et al., 2002) and epistemological beliefs (Hofer & Pintrich, 1997). The NOS dimensions are named *source*, *certainty*, *development*, *justification of scientific knowledge* and the *purpose of science* (Urhahne, Kremer, & Mayer, 2008).

The *source of scientific knowledge* refers to the possibilities of contribution to the scientific progress. Many scientific theories were generated by professional scientists who spent a lot of their lifetime conducting scientific research. But in the same way, people without a deeper education in science, who are curious, imaginative and creative, can contribute to scientific knowledge (Conley et al., 2004; Elder, 2002; McComas & Olson, 1998).

The *certainty of scientific knowledge* refers to its reliable but never absolutely certain nature. Scientific theories and concepts always have to be considered as tentative and subject to change in light of new evidences. Different theories explaining the same phenomenon can be equally accepted as long as no opposing proofs exist. However, it is inadequate to believe that scientific problems do only have one absolutely true answer (Lederman et al., 2002; McComas & Olson, 1998; Osborne et al., 2003).

The *development of scientific knowledge* refers to the fact that scientific knowledge is permanently subject to change, which is supported by new technologies and improved research methods. The social and cultural circumstances play a decisive role in the development of scientific knowledge as well. The history of science reveals the evolving and revolving character of scientific research (McComas & Olson, 1998; Osborne et al., 2003).

The *justification of scientific knowledge* is based on observations, experiments and logical explanations. No single scientific method exists but all scientific explanations should be supported by empirical evidence and tested against the natural world. It is important to realize the relationship between observations and inferences. Observations and data from experiments can be used to draw inferences in order to justify a scientific claim, but a single experiment is not enough to prove a scientific theory (McComas & Olson, 1998; Osborne et al., 2003).

The *purpose of science* is the description, explanation and prediction of natural phenomena. Human experiences with nature are classified in science in order to solve scientific problems (Driver, Leach, Millar, & Scott, 1996; McComas & Olson, 1998).

Rationale

The research presented here focuses on the assessment of inquiry competencies (Weinert, 1999, 2001) and their relation to beliefs on the nature of science. Understanding scientific inquiry can be beneficial for understanding the nature of science and vice versa because both competencies can be promoted simultaneously by experimenting and explicit, reflective instruction in science class (Khishfe & Abd-El-Khalick, 2002). The study illuminates the central features of inquiry and NOS competencies and discusses the educational implications for science teaching. In this context, the following research questions are more closely examined:

1. Do NOS beliefs and inquiry competencies develop when students are in higher grades?
2. Is there a relationship between NOS beliefs and inquiry competencies?
3. To what extent can science experience, science performance and NOS beliefs explain inquiry competencies?

Methods

Participants

The study was conducted with 1553 secondary school students who worked on a paper-and-pencil test on inquiry competencies. Students were in fifth ($n = 251$), sixth ($n = 238$), seventh ($n = 345$), eighth ($n = 223$), ninth ($n = 275$) and tenth ($n = 221$) grade. This sample was used for Rasch modeling of students' inquiry competencies. In addition, 218 students (114 female, 104 male) filled in a questionnaire on NOS beliefs. These secondary school students were in seventh ($n = 50$), eighth ($n = 58$) and ninth ($n = 110$) grade.

Materials

Inquiry competencies. A paper-and-pencil test was used to measure students' inquiry process skills *formulating questions, generating hypotheses, planning investigation* and *interpreting data*. Students had to answer open-ended questions, which are most suitable for assessing problem-solving skills. The items contained a short description of a biological problem in a real-world situation and, depending on the addressed process skill, one or two questions. The test instrument comprised 24 items, which were adapted in difficulty to students' grade level. All test items were distributed in booklets in a multi-matrix-design with overlapping items linking the test booklets to each other. Every examinee responded to a test booklet containing six items from each process skill.

Data were analyzed by assigning students' answers to five levels of competence by means of a scoring guide. The scoring guide was grounded in a deductive manner on theoretical and empirical literature concerning levels of inquiry process skills as well as standards documents. The evaluation schema contained 10 to 13 different codes specifying the levels of competence of every process skill (Mayer et al., 2009). The applied competence levels proceed in complexity and draw attention to the quality of students' problem-solving strategy (Mayer et al., 2009; Möller, Grube, Hartmann, & Mayer, 2009). Two researchers coded students' answers independently. Cohen's κ for interrater reliability was found to be very good, ranging from .88 to 1.00 for all process skills.

Rasch analysis was used for modeling inquiry competencies by means of the computer program *ConQuest* (Wu, Adams, & Wilson, 1997). The Rasch procedure bears several advantages. First, Rasch analysis helps to convert the categorical data derived from the coding process in a way that distances can be explained in terms of interval linear measures. Second, measurement of students' ability must not only be derived from the few effectively solved test items, but can be estimated more precisely from all items used in the aforementioned multi-matrix-design throughout the test population (Adams & Wu, 2002). Additionally, background variables that might influence a person's latent ability can be comprised to the estimation. In this study, age, years of education and biology grades were used as background variables (Wu et al., 1997).

Using ConQuest, a four-dimensional Rasch model, assuming every process skill as one dimension of the model, was calculated. ConQuest calculates five plausible values (PVs) for every person in every assumed dimension (Wu et al., 1997). PVs represent random draws from an empirically derived distribution of estimates that are conditional on the observed values of the test items and the background variables. PVs are logarithmic transformations of the odds (logits) that give information about students' chance to solve the items of the test instrument correctly. They are a measure of students' competence.

The test instruments' quality was pointed out by following analyses. To check the reliability of the test instrument, EAP/PV reliability was calculated. This estimate refers to the response variance and thus is based on the same construct as Cronbach's α (Bond & Fox, 2001). Reliabilities of the scales were .59 for *formulating questions*, .69 for *generating hypotheses*, .69 for *planning investigation*, and .75 for *interpreting data*. Reliability values are within the acceptable range for open-ended items. Concerning the test instruments internal validity, item fit analyses were conducted. Item fit values show how well an item fits to the construct that should be measured (Adams & Wu, 2002). In this study, weighted MNSQ values (wMNSQ) were calculated. All items resulted in satisfying infit values within the acceptable range ($0.8 < \text{wMNSQ} < 1.2$). Additionally, the critical t-values of all items were within the acceptable range between -2 and +2 (Adams & Wu, 2002; Wu et al., 1997). Critical t-values in the given range indicate that the respective fit does not deviate significantly from the distribution of all the fits. In consequence, it can be said that the calculated four-dimensional Rasch model fits the data of students' inquiry skills. Correlations to science performance provide additional evidence for the criterion-oriented external validity of the measuring instrument. Findings are reported in the results section.

Table 1. Sample items, number of items, and reliability of five NOS scales.

Scale	Sample Item	Number of Items	Cronbach's α
Source	Only scientists can think of scientific research questions. (-)	5	.55
Certainty	Approved scientific theories should not be questioned anymore. (-)	7	.68
Development	Sometimes scientific assumptions change.	8	.66
Justification	In science, there are different ways to test assumptions.	9	.60
Purpose	Scientists conduct experiments to make new discoveries.	5	.61

NOS beliefs. A questionnaire was used to measure students' beliefs on the nature of science. All items were rated on a 5-point Likert scale (1 = *absolutely not true*, 2 = *somewhat true*, 3 = *partly true*, 4 = *rather true*, 5 = *absolutely true*). Measurement with the Likert scale implies a development of students' beliefs from a naïve to a relativistic understanding of the epistemology of science (Hofer & Pintrich, 1997). The questionnaire was developed on the basis of core dimensions of NOS understanding. The items were derived from examining literature on a range of assessment instruments on the nature of science and epistemological beliefs. In a pilot study with secondary school students seven scales emerged from factor-analysis with satisfying reliability (Urhahne et al., 2008). Criterion-oriented external validity of the scales was demonstrated in former studies by calculating correlations to science performance, domain-specific self-concepts, and a science term knowledge test (Kremer, Urhahne, & Mayer, 2008, 2009; Urhahne et al., 2008; Urhahne, Kremer, & Mayer, submitted). In this study, two scales of the original questionnaire were excluded because it was found that the *simplicity of scientific knowledge* and the *creativity of scientists* are barely understood by secondary school students (Urhahne et al., 2008). The reliabilities and sample items of the five NOS scales are provided in Table 1. The reliability of the scales is within the acceptable range for measuring epistemological beliefs (Muis, Bendixen, & Härle, 2006).

Socio-demographic variables. Besides gender, age, and grade level students were asked of their grades in biology. Biology grades ranged from 1 (best grade) to 5 (worst grade).

Procedure

The whole investigation took place during students' regular biology lessons in the presence of their teachers. Students worked on the inquiry test and NOS questionnaire, which lasted about forty-five minutes.

Results

The first research question asks of the development of inquiry skills and NOS beliefs. The statistical analyses to this question are shown in Tables 2 and 3.

Table 2. One-way analyses of variance of four inquiry competencies by grade level.

Scale	Grade 7 <i>n</i> = 50	Grade 8 <i>n</i> = 58	Grade 9 <i>n</i> = 110	<i>F</i> (2, 215)
Formulating questions	-.23 ^a (.71)	-.43 ^a (.58)	.06 ^b (.57)	13.23***
Generating hypotheses	.25 ^a (.95)	.07 ^a (.87)	.70 ^b (.95)	9.92***
Planning investigation	-.19 ^a (.98)	-.10 ^a (.87)	.45 ^b (.80)	12.76***
Interpreting data	.69 ^a (1.20)	.68 ^a (1.17)	1.61 ^b (1.12)	17.64***

Note. **p* < .05, ***p* < .01, ****p* < .001. Letters indicate homogeneous sub-groups.

Table 2 shows the means of plausible values (PVs) of the four inquiry process skills for seventh, eighth and ninth graders. The first plausible value of every dimension of the Rasch model can be used to represent students' inquiry competence. PVs are given on a logit-scale ranging from negative values for decreasing inquiry competence to positive values for increasing inquiry competence. As PVs are linear measures, they can thus be used as in

classical test theory. One-way analyses of variance (one-way ANOVAs) were performed to compare students' inquiry competencies by grade level. As depicted in Table 3, students' inquiry skills in all four processes increased significantly from grade 7 to grade 9. Letters in Table 3 indicate significant differences between groups as revealed by post-hoc Tukey's HSD tests. Ninth graders showed higher developed inquiry competencies compared to seventh and eighth grade students.

Table 3. One-way analyses of variance of five NOS dimensions by grade level.

Scale	Grade 7 <i>n</i> = 50	Grade 8 <i>n</i> = 58	Grade 9 <i>n</i> = 110	<i>F</i> (2, 215)
Source	3.93 ^{ab} (.71)	3.68 ^a (.77)	4.10 ^b (.63)	6.71 ^{**}
Certainty	4.13 ^{ab} (.84)	3.79 ^a (.80)	4.44 ^b (.70)	12.87 ^{***}
Development	3.66 ^{ab} (.63)	3.52 ^a (.50)	3.84 ^b (.57)	6.08 ^{**}
Justification	3.85 ^a (.53)	3.85 ^a (.50)	4.10 ^b (.44)	6.81 ^{**}
Purpose	3.74 ^a (.72)	4.08 ^b (.56)	3.95 ^{ab} (.65)	4.06 ^{**}

Note. **p* < .05, ***p* < .01, ****p* < .001. Letters indicate homogeneous sub-groups.

Table 3 depicts the one-way ANOVAs for the five dimensions of NOS beliefs with respect to grade level. Ninth grade students show the most advanced NOS beliefs. Except for the dimension *purpose*, post-hoc analyses by means of Tukey's HSD procedure reveal the most relativistic position of ninth graders as indicated by letters in Table 4. Eighth grade students hold on average nearly the same beliefs as seventh graders but were more competent when stating the purpose of science. Seventh grade students show the most naïve beliefs on the dimension *purpose*. The findings are in line with the assumption that NOS beliefs develop over time and students in higher grades possess a more sophisticated NOS understanding.

Table 5. *Pearson correlations between inquiry competencies, NOS beliefs, and biology grades.*

	Formulating questions	Generating hypotheses	Planning investigation	Interpreting data
Source	.37 ^{***}	.33 ^{***}	.26 ^{***}	.37 ^{***}
Certainty	.37 ^{***}	.28 ^{***}	.23 ^{**}	.31 ^{***}
Development	.24 ^{**}	.17 [*]	.20 ^{**}	.26 ^{***}
Justification	.19 ^{**}	.08	.24 ^{**}	.22 ^{**}
Purpose	.20 ^{**}	.02	.26 ^{**}	.16 [*]

Note. **p* < .05, ***p* < .01, ****p* < .001.

The second research question asks whether there is a significant relationship between inquiry competencies and NOS beliefs. Table 5 shows the Pearson correlation coefficients between the first PVs of the four inquiry process skills and the five NOS scales. As hypothesized, small but significantly positive correlations occur. Students with higher scientific reasoning skills hold more informed views on the nature of science. *Source* and *certainty* beliefs are consistently related to inquiry process skills. The scale *source* deals with students' conviction that only professional scientists but not they themselves can contribute to scientific knowledge. The scale *certainty* measures students' awareness of the never absolutely certain character of scientific knowledge and the possibility of different acceptable explanations for scientific problems and phenomena. The higher *source* and *certainty* beliefs are, the more are students able to find solutions for scientific problems by formulating research questions, generating hypotheses, planning investigations and interpreting scientific data. In addition, Table 5 shows significantly negative correlations between students' inquiry skills and biology grades indicating that high performing students possess better inquiry process skills.

The third research question deals with the contribution of years of education, science performance and NOS beliefs to the explanation of students' inquiry competencies. A hierarchical linear regression analyses with inquiry competencies as dependent variables was performed. In the first step, school year and biology grades were taken in the regression equation. As expected, both control variables contribute substantially to the explanation of students' inquiry competencies as indicated by the significant standardized regression coefficients. The coefficient of determination R^2 shows the explained variance in inquiry competencies by the variables school year and grades. It ranges from .17 for *formulating questions* up to .28 for *interpreting data*. In the second step, the five NOS beliefs were taken up in the regression equation to explore their additional contribution to the explanation of inquiry competencies. *Source* as well as *certainty* beliefs can be found to contribute significantly to students' inquiry competencies. For *formulating questions*, the two NOS belief dimensions enhance the explanatory power of the regression model from .17 to .28. In three of four cases, the inclusion of NOS beliefs into regression analyses led to a significant increase of explained variance in inquiry competencies.

Conclusions and Implications

In this study, secondary school students' inquiry and NOS competencies were analyzed by means of a newly developed inquiry test instrument and a NOS questionnaire. Both measuring instruments show satisfying reliability and validity and are suitable for assessing core concepts of scientific literacy.

Results to the first research question reveal that students in higher grades received higher scores in the inquiry competence test and showed more relativistic beliefs on the nature of science. Although only students from seventh, eighth, and ninth grade were compared with each other, there is a clear developmental trend in the data. It suggests that students display better inquiry and NOS competencies when they have more learning experiences in school. Whereas students' growth of inquiry competencies is an expected result due to regular practice in German science class, the improvement of NOS beliefs is remarkable. Contrary to this finding, Kang et al. (2005) reported for a sample of Korean students that sixth graders' view on the nature of science does not differ clearly from those of eighth and tenth graders. Further research has to show if NOS beliefs really develop in secondary school students and how purposeful instruction on NOS issues can contribute to an improved perspective on epistemological questions.

The second research question was directed to the relationship between inquiry and NOS competencies. Positive correlations between inquiry skills and NOS beliefs suggest that both concepts have something in common which can be described from a theoretical perspective as a focus on processes of scientific knowledge acquisition. However, as the correlation coefficients are on medium level, the conclusion can be drawn that further components distinguish the two concepts from each other. The findings correspond with results derived from intervention studies on inquiry skills and NOS understandings. Instructional approaches focusing on the promotion of inquiry processes that heighten NOS understandings as well have been extensively studied in science education research

(Khishfe & Abd-El-Khalick, 2002; Bell et al., 2003). As NOS understanding was originally considered to be an automatically developing outcome of teaching science as inquiry (Moss, Abrams, & Robb, 2001), recent studies raised this assumption to question. Moreover, it was found that students' NOS beliefs are not easy to change by inquiry activities (Khishfe & Abd-El-Khalick, 2002; Bell et al., 2003).

According to Khishfe and Abd-El-Khalick (2002), two instructional approaches to develop inquiry and NOS understandings can be distinguished: 1) the implicit approach is based on the assumption that having students do science will also result in more adequate NOS understandings; 2) the explicit approach implies that NOS aspects have to be intentionally planned and taught rather than expected to be a by-product of engaging students in science activities. Exploring the influence of an implicit approach, Bell et al. (2003) examined the impact of an 8-week science apprenticeship program on a group of secondary students' understandings of NOS and inquiry. Although most students gained knowledge about the processes of scientific inquiry in lab work, their NOS conceptions remained unchanged. Sandoval and Morrison (2003) explored the effects of a biological unit to guide students' inquiry into phenomena of evolution by emphasizing explicitly the nature of scientific causal explanations. Sandoval and Morrison (2003) report no changes in students' NOS understandings derived from students' expressed ideas about NOS in interviews before and after the treatment. Khishfe and Abd-El-Khalick (2002) investigated in an intervention study the influences of explicit versus implicit inquiry-based instruction on sixth graders' NOS conceptions. One group of students was engaged in inquiry activities followed by an explicit discussion of related aspects concerning the tentative, empirical, inferential, and imaginative and creative NOS. Another group of students was engaged in the same inquiry activities but in an implicit manner without targeting NOS aspects specifically. As a result, Khishfe and Abd-El-Khalick (2002) reported that substantially more participants in the explicit group in comparison to the implicit group developed improved NOS conceptions throughout the intervention. Accordingly, engaging students in doing science and science processes is the right way, but not enough to proceed from inquiry to sophisticated NOS conceptions. Due to positive but far from perfect correlation coefficients between inquiry skills and NOS beliefs, it can be stated that inquiry processes can introduce the formation of NOS understandings but learners are in need of explicit instructional support to connect science processes adequately to NOS understandings.

According to the third research question, study results reveal that NOS beliefs in addition to science experience and prior achievement contribute to inquiry competencies and thus might facilitate scientific reasoning and problem solving (Hofer & Pintrich, 1997; Lin et al., 2004). As reported above, fostering of NOS understandings by engaging students in inquiry-based science learning approaches is broadly considered in research and policy documents but, conversely, little research work explicitly addressed the influence of students' NOS beliefs on their inquiry strategies (Sandoval & Morrison, 2003). Dunbar (1993) found that instructing students to generate their own explanations from data encourages them to evaluate data more carefully in relation to potential causal explanations. Similarly, sixth graders receiving explicit instruction about the purpose of experimentation were more able to design controlled experiments (Schauble et al., 1995). It follows that students' more precise knowledge and beliefs about NOS influence the reasoning strategies they use during inquiry.

The questions arises as to whether experiences in inquiry processes primarily influence learners' NOS beliefs or existing NOS beliefs determine the ways in which learners realize inquiry processes (Sandoval, 2005; Mayer, 2007). Further research is needed to explore the discussed interactions between NOS and inquiry as well as the importance of these for science learning and instructional processes. Future assessment studies on students' competencies carried out by the *Institute for Educational Progress* (IQB) will use similar competence test items (Mayer et al., 2009; Walpuski et al., 2008) and the reported NOS questionnaire (Urhahne et al., 2008) to confirm the research results and to analyse relationships of inquiry and NOS competencies to further constructs like science knowledge. The expected outcome will be an improved understanding of concepts constituting scientific literacy, which can be seen as the basis for students' life-long learning in the sciences.

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THE ROLE OF EPISTEMOLOGICAL BELIEFS IN HIGH SCHOOL STUDENTS' LEARNING STRATEGY

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Abstract

This study examined the role of high school students' epistemological beliefs in their learning strategy use in chemistry course. Three hundred forty eight high school students from different grade levels in Turkey participated in the study. Motivated Strategies for Learning Questionnaire and the Epistemological Beliefs Questionnaire were used to measure students' learning strategies and epistemological beliefs, respectively. The learning strategies included rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation; while students' epistemological beliefs consisted of three dimensions (effort, ability, and unchanging truth). Through structural equation model (SEM) analysis, the fit indices indicated a good model fit. Only effort dimension of epistemological belief was a significant predictor of students' learning strategies. This finding indicates that students, who believe that learning can be improved by increasing effort, use learning strategies more frequently.

Introduction

Epistemology deals with individuals' beliefs about the nature of knowledge and knowing. Hofer and Pintrich (1997) define epistemology as "an area of philosophy concerned with the nature and justification of human knowledge" (p.88). Researchers propose different models to explain students' epistemological beliefs. These models can be mainly classified as developmental and multidimensional models. Developmental models include Perry's Scheme of Intellectual and Ethical Development (Perry, 1970); Women's Ways of Knowing (Belenky et al., 1986); Epistemological Reflection Model (Baxter Magolda, & Porterfield, 1985); Reflective Judgment Model (King & Kitchener, 1994), and Argumentation Reasoning (Kuhn, 1991). These models suggest that students' epistemological beliefs develop in a sequence. On the other hand, multidimensional models suppose that epistemological beliefs consisted of independent beliefs (Schommer, 1990; Hofer & Pintrich, 1997; Hammer & Elby, 2002). As a result, students can hold more sophisticated epistemological beliefs in one dimension and more naive beliefs in another.

In this study multidimensional perspective was considered. Schommer (1990) developed a questionnaire based on multidimensional perspective including students' beliefs about knowledge and learning. In her initial study, Schommer (1990) proposes five independent dimensions (simple knowledge, omniscient authority, certain knowledge, innate ability, and quick learning) stated from a naive epistemological perspective. However, empirical studies supported only four dimensions except for omniscient authority. Researchers criticize the questionnaire because of the low validity and reliability issues (Muis, 2004; Pintrich & Hoffer, 1997). Despite the methodological

problems mentioned in the literature, this questionnaire has been widely used. The development of epistemological belief questionnaire facilitated succeeding empirical studies investigating the relationship between epistemological beliefs and several learning outcomes (Hofer & Pintrich, 1997). The four dimensional version of the epistemological belief questionnaire was widely used in the literature; however, in one study Neber and Schommer-Aikins (2002) used six dimensional scale (belief in innate inability for knowing; belief that success is unrelated to work; belief in quick learning; belief in seeking single answers; belief in avoiding integration of knowledge; and belief in certain knowledge) to examine high school students epistemological beliefs.

Results of empirical studies have shown the role of students' epistemological views in their learning process and the ways knowledge is constructed. Studies provide empirical evidence for direct and indirect paths between students' epistemological beliefs and academic achievement. Schommer (1993) found that students' epistemological beliefs' predict their GPA. On the other hand, students' learning approaches (Cano, 2005) or self-regulatory learning skills (Barnard, Lan, Crooks & Paton, 2008) were found to be mediating this relationship. Meanwhile, a large body of literature examines the relationship between students' epistemological beliefs and learning strategies. Students holding more sophisticated beliefs employ meaningful learning or deep processing strategies frequently and are active in their learning process. On the other hand, students with naive epistemological views use rote memorization strategies or inadequate strategies (Dweck & Leggett, 1988; Hogan, 2000; Qian & Alvermann, 1995, Sandoval, 2005; Schommer, 1990; Schommer, 1993; Schommer, Crouse & Rhodes, 1992). In some studies, indirect paths between students' epistemological beliefs and strategy use were found. For example, in one study utilizing SEM "success does not require work" dimension of epistemological belief questionnaire was a significant predictor of self-regulatory strategy use, while self-efficacy was the mediator variable (Neber & Schommer-Aikins, 2002).

Rationale

Adequate understanding of epistemology is important in order to promote meaningful learning in the classroom. Subsequent studies are required to get better understanding of the relationship between students' epistemological beliefs and several academic learning outcomes. Accordingly, the purpose of this study was to examine the role of high school students' epistemological beliefs in their learning strategy use in chemistry course. Students holding more sophisticated epistemological beliefs were expected to use learning strategies more frequently.

Methods

Subjects of the Study

A total of 348 students from different grade levels (129 ninth, 114 tenth and 105 eleventh graders) from a public high school in Ankara in Turkey participated in the present study. Approximately 44% of the students were females (N=155), 51% (N=177) were males, and 5% (N=16) did not respond gender item.

Procedure

The instruments were administered by the researchers during class hours throughout the spring semester of the 2007-2008 academic year. It took approximately 20 minutes to complete the instruments. Students were informed about the confidentiality of the results.

Instrument

Motivated Strategies for Learning Questionnaire (MSLQ) and The Epistemological Belief Questionnaire (EBQ) were used as instruments.

Motivated strategies for learning questionnaire

It was originally developed by Pintrich, Smith, Garcia, and McKeachie (1991), and translated and adapted into Turkish by Sungur (2004). The learning strategies section of MSLQ was administered to high school students to measure their learning strategies in Chemistry course. The strategies included five cognitive and metacognitive strategies: rehearsal, elaboration, organization, critical thinking, and metacognitive self regulation. Students rate themselves on a seven point Likert type scale ranging from 1 (not at all true for me) to 7 (very true for me).

The factor structure proposed in the original scale was tested conducting Confirmatory Factor Analysis using LISREL 8.30 for Windows (Jöreskog & Sörbom, 1993). The fit indices were found within acceptable limits (Root Mean Square Error of Approximation (RMSEA) = .09, the Standardized Root Mean Square Residual (SRMR) = .07, Non-Normed Fit Index (NNFI) = .77, and Comparative Fit Index (CFI) = .79) and confirmed the factor structure proposed in the original scale (Kline, 1998). The Cronbach's alpha coefficients were found between .73 and .83 indicating adequate internal consistency.

Epistemological belief questionnaire

The Epistemological Belief Questionnaire developed by Schommer (1990) was administered to measure students' epistemological beliefs. The original scale consisted of 63-items measuring four dimensions (innate ability, simple knowledge, quick learning, and certain knowledge). The items were written in the naive epistemological perspective. The scale was adapted to Turkish culture by Deryakulu and Buyukozturk (2002). The number of items was decreased to 35 and they found evidence for three dimensional factor structure. Since the items in each dimension were somehow different from the original scale, they assigned new names to the dimensions: The belief of learning depends on effort (shortened as *effort* in this study), the belief of learning depends on ability (shortened as *ability* in this study), and the beliefs that there is only one unchanging truth (shortened as *unchanging truth* in this study). Students rated themselves on a five point Likert type scale ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores indicated more sophisticated beliefs.

When Confirmatory Factor Analysis was performed to test the factor validity of the Turkish version of the scale, the fit indices were found to be .07 for RMSEA, .08 for SRMR, .62 for NNFI and .65 for CFI. These values were within acceptable limits, except for NNFI and CFI (Kline, 1998). The Cronbach alpha coefficients were .75 for effort dimension, .58 for ability dimension, and .56 for unchanging truth dimension. Although the Cronbach alpha values for the effort and unchanging truth dimensions were low, these values were close to the values reported in the literature (Schommer, 1993; Deryakulu & Buyukozturk, 2002; Deryakulu & Buyukozturk, 2005).

Analysis of Data

Considering related literature, a structural equation model (SEM) was employed in which learning strategy variable was predicted by three dimensions of epistemological belief questionnaire. Learning strategy (latent variable) had five indicators: rehearsal, elaboration, organization, critical thinking, and metacognitive self regulation. It is expected that students holding more sophisticated epistemological beliefs tend to use learning strategies more frequently.

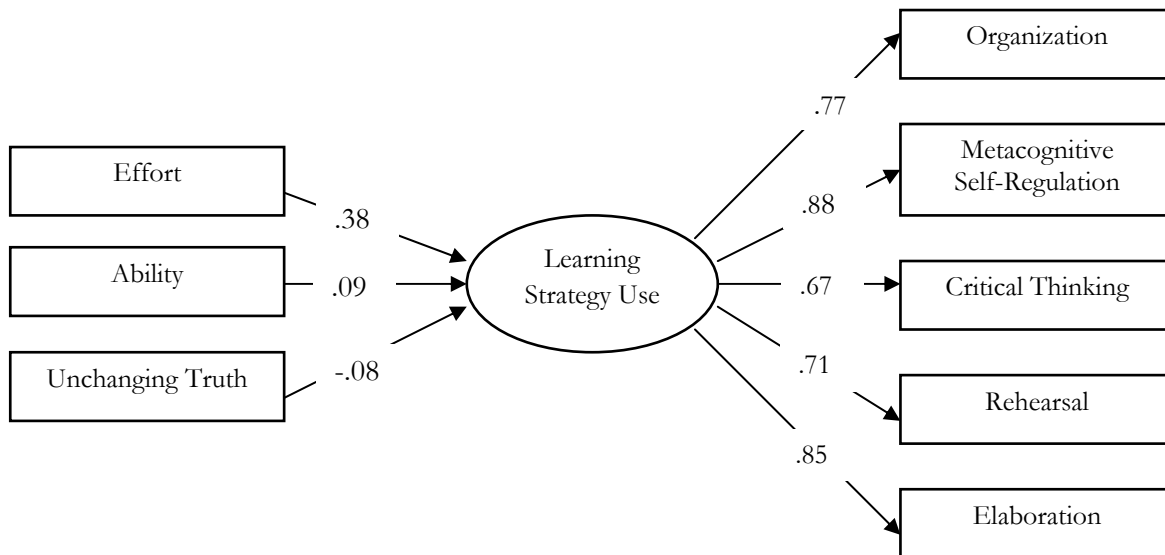
Results

Table 1 displays descriptive statistics for each subscale of the two questionnaires. The mean scores for each dimension of both instruments were found around midpoint.

Table1. Descriptive statistics for the subscales of MSLQ and EBQ.

Subscale	Mean	Standard Deviation
Rehearsal	4.12	1.33
Elaboration	4.31	1.19
Organization	4.42	1.32
Critical thinking	3.99	1.29
Metacognitive self-regulation	4.23	.94
Effort	2.96	.46
Ability	2.57	.63
Unchanging truth	2.30	.51

Through SEM analysis, the fit indices indicated a good model fit with the values .97 for Non-Normed Fit Index (NNFI), .99 for Comparative Fit Index (CFI), except for the Root Mean Square Error of Approximation (RMSEA) with the value .125 (Kline, 1998). The five strategy indicators made significant contribution to the latent variable *learning strategy*: all of the path coefficients ranged from .67 to .88. Only the effort dimension of the EBQ was a significant predictor of learning strategy. The standardized path coefficient was found to be .38, indicating medium effect size corresponding to Cohen's criteria with the value around 0.30 (as cited in Kline, 1998). However, ability and unchanging truth dimensions of EBQ did not contribute significantly to the learning strategy.



Note: NNFI = .97; CFI = .99; RMSEA= .125

Figure 1. Structural Model of Learning Strategy Use.

Conclusions and Implications

In this study, the role of epistemological beliefs on high school students' learning strategy use was investigated. Multidimensional structure was considered while investigating students' epistemological beliefs. The findings showed that only the effort dimension of the EBQ was significantly contributed to the learning strategy latent variable. This finding indicates that students, who believe that learning can be improved by increasing effort, use learning strategies more frequently. However, the belief that intelligence can be developed and there is not one unchanging truth, do not affect students' strategy use. The results can also be explained with the Attribution theory of motivation (Weiner, 2000): Students, who attribute failure to effort, do not give up easily when they failed and show adaptive reactions after failure such as increasing effort.

In this study, only the direct paths between dimensions of epistemological beliefs questionnaire and learning strategy use were tested. However, there may be indirect paths explaining the relationship between these constructs. For example, Neber and Schommer-Aikins, (2002) found self-efficacy as the mediator variable between one dimension of epistemological belief questionnaire and self-regulatory strategy use. In addition, Muis (2007) proposes a theoretical model suggesting that students' epistemological beliefs can influence their goal orientations and in turn students' goal orientations can affect their study strategies and accordingly academic achievement. Different constructs associated with classroom environment or learning outcomes can be examined (such as students' goal orientations, self-efficacy beliefs and academic achievement) to test more comprehensive models including direct and indirect paths.

The current study has significant contributions to the practice. In order to help students possess sophisticated epistemological views, chemistry teachers should emphasize constructivist nature of science in their instruction. Accordingly, teachers should promote open inquiry and argumentation through classroom discussions, conduct scientific observations or experiments rather than simply using lecturing methods and traditional assessment methods such as asking multiple choice questions requiring one correct answer.

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RELATIONSHIP BETWEEN HONG KONG STUDENTS' UNDERSTANDING OF THE NATURE OF SCIENCE AND THEIR ATTITUDE TOWARDS SCIENCE

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Abstract

The current study aims to investigate the possible relationship between student understanding of the nature of science (NOS) and their attitude towards science (ATS), and exploring whether improving students' understanding on NOS would improve students' ATS, and also on students' academic performances. Improving NOS understanding in students is done by incorporating NOS teaching into normal integrated science lessons science teaching. Two groups of Hong Kong grade 8 students are involved in the present study: one group with NOS teaching infused in the science lessons, while another one without NOS teaching, serving as the control. Pre-test and post-test were carried out to elucidate the improvement of NOS understanding of the two groups, and it was shown that NOS instruction is effective in improving students' understanding on NOS. Quantitative survey on students' ATS did show significant increment in students' value of science in society, and learning NOS maybe useful in slowing down the dying of students' interest in learning science. Evidence is obtained to suggest the possible relationship between NOS understanding and academic performances. From the interviews, students reflected that they gained much interest towards learning science through learning about NOS, as it provides them with a complete picture of the ways that scientific knowledge is constructed, giving them a sense of empowerment that they can solve problems by themselves.

Introduction

NOS – the international trend

Gaining understanding in nature of science (NOS) is one of the important goals of science education worldwide. The understanding of 'science as a way of knowing' has been put into global science curricula and syllabi with exceptionally high priority, as seen in various international science education standard documents (McComas & Olson, 1998). Examples from the US included the 'Project 2061: Science for all Americans' (AAAS, 1989), and also in the "Benchmarks for scientific literacy" (AAAS, 1993), raised since the early 90s. In the UK, NOS have been emphasized in the "Science in National Curriculum" (DFE, 1995), and by Millar & Osborne (1998) in "Beyond 2000: Science education for the future". In Canada, in the "Common framework of science learning outcomes" (Council of Ministers of Education, 1997), a discrete section or separated chapter is devoted to NOS.

NOS teaching emerging in Hong Kong

Hong Kong followed the world trend since 2000. Ideas of promoting NOS understanding started to emerge in curriculum documents. NOS has been introduced to the junior science curriculum in 2000, that "On completion

of the junior secondary level, students should...recognize the usefulness and limitations of science and the evolutionary nature of scientific knowledge” (Curriculum Development Council, 2002c, p.22), and NOS is also introduced to senior Physics, Chemistry and Biology curriculum in 2003. In the new secondary system launched in 2009, the emphasis on NOS is even stronger and more notable (CDC and HKEAA, 2007). From these documents, one can see that the importance of NOS in Hong Kong science education is increasing. In order to promote learning and teaching of NOS, the Hong Kong Government funded a series of projects and professional development seminars, which have been supporting teachers to learn how to teach NOS in science classrooms. Most of the teaching materials used in the intervention of the present study were developed in these projects to promote NOS learning and teaching in Hong Kong.

Rationale

Various reasons were put forth to support teaching of NOS, among them Driver, Leach, Miller and Scott (1996) suggested that understanding of NOS could help students to “(make)...sense of science and manage the technological objects and processes in everyday life” (p.16), to “make sense of socio-scientific issues and participate in the decision-making process” (p.18), to “to appreciate the value of science as part of contemporary culture” (p.19), to “develop awareness of the nature of science, and in particular the norms of the scientific community, embodying moral commitments which are of general value” (p.19), and “supports successful learning of science content” (p.20). McComas, Clough & Almazroa (1998, p.13) also suggested that learning NOS can enhance interest in science, as “a sensitivity in the development of scientific knowledge may also make science itself and science education more interesting”. And “... mistaken ideas of science likely affect students’ attitudes toward science and learning in science classes” (Clough and Olson 2004 p.28).

Yet no empirical study has focused on the effects of teaching NOS on promoting students’ attitude and interest in science. In his recent review, Lederman (2007) pointed out this missing compartment in the literature, that “...empirical support for our intuitive claims is nowhere to be found. Hence, all of the reasons we have always used for advocating NOS as an instructional outcome may be false.” (p. 872).

It is the aim of the present study to find out any possible relationships between students’ understanding of NOS and their attitudes towards science. The research questions of the present study are: Does the learning of NOS improve students’ (a) attitude towards science, and (b) learning of content knowledge? It is hypothesized that students who have a deeper understanding of NOS would have a more positive attitude towards science, therefore, it is reasonable to contend that increasing students’ understanding on NOS may have a positive effect on their attitude, and in turn on their learning of science.

Methods

Subjects

116 secondary two (equivalent to grade 8 in the US-system) students from a school of Hong Kong participated in the present study. 76 of them formed the experimental group, and the rest of the 40 students formed the control group. There were no significant differences between the subject test results of the two groups before the intervention, as shown by the T-test results. The first author was the science subject teacher to both groups throughout the academic year when the investigation was conducted.

Intervention

The intervention lasted for a total of 12 lessons in 6 months. Students in the experimental group were taught with an “NOS-integrated” curriculum, in which NOS teaching were infused into the original teaching, so that students can learn NOS explicitly when engaged in various activities. Teaching activities carried out were listed in Table 1.

Students in the “control class” were taught with an “NOS-free” curriculum, in which no NOS theme were taught explicitly during normal teaching, though there were chances that the students might still learn certain NOS aspects implicitly from the original curriculum. Compensative activities related to the curricular topics, but with no explicit connection to NOS, were carried out in the control class in order to equalize their exposure time to science with the experimental group. Teaching activities for the control class are also listed below in Table 1.

Table 1. Teaching activities of the Experimental group and the Control group

Timeline	Teaching Topics	Teaching activities	
		Control group	Experimental groups
Oct 2007	Living Organisms and Air	Discussion on structured question on the topics	Group discussion on how scientists interpret the data on average global temperature to give different conclusions on global warming.
Nov 2007		Video on effect of smoking on health	Group discussion on a scenario about scientists investigating Asthma in children in UK, and to decide on which causes of asthma they should invest time and money to investigate.
Dec 2007		Practical work on photosynthesis on variegated leaves	Historical approach – The story of the discovery of photosynthesis.
Jan 2008	The use of electricity	Detailed calculations of electricity consumption and on domestic electricity bill	Historical approach – The story of the debate between Galvani & Volta on how current electricity is generated.
Feb 2008	Common acids and alkalis	Investigations: 1. Effects of acid rain on seed germination 2. Effect of concentration of vinegar on food deterioration	To design an experiment to investigate the effect of acid rain on the growth of seedlings.
Mar 2008	Detection of the environment	Video on sensory organs	By learning about LASIK and how ancient Chinese treated short-sightedness, to discuss the relationship between science and technology
Apr 2008	Summary	Discussion on structured questions on the topic	Students are asked to cut holes on an envelope, to peek and draw the picture of a fish inside – a “parable” of how science helps humankind to learn about the nature.

Instruments – Questionnaires with interviews

A modified “Views of Nature of Science Questionnaire - version D” (VNOS-D, Abd-El-Khalick et. al. 2001) was employed to probe students’ understanding of NOS. In the VNOS-D only those questions related to the teaching materials employed in the intervention were chosen. Students were asked to complete the open-ended questionnaire before and after the intervention. And upon the completion of the questionnaires, 25% of the subjects were selected randomly for clarification of their written responses.

The second questionnaire employed was the “Attitude Towards Science Inventory” (ATSI) (Young 1998), which includes 48 items in a 4-point Likert scale, testing on students’ attitudes in 6 categories, namely the “Perception of the science teacher”, “Anxiety towards science”, “value of science in society”, “self-concept of science”, “enjoyment of science”, and “motivation in science”. It is noted that only the ‘value of science’, the ‘enjoyment of science’, and the ‘motivation of science’ are considered in the present study, as they are directly related to the research interest of this project. Students with a positive ATS were then interviewed to elucidate on the plausible reasons for them to have an interest towards learning science.

After the intervention, the ATSI was again carried out among the students, and those with notable changes in ATS are interviewed to elucidate their reasons for their changes. Selection criteria for having ‘notable’ change was that a particular student is having an increment or decrement of his average score of 0.5 (Likert-scale of 1 to 4) in the following dimensions: The ‘value of science’, the ‘enjoyment of science’, and the ‘motivation of science’, or the overall ATSI score.

Results

Changes in NOS understanding

The change of students’ understanding of NOS is analyzed and were converted into quantitative scores, representing students’ understanding. Table 2 below shows the results of the comparison between the pre- and post-test, and the mean scores represented the increment (positive figures) or the decrement (negative figures) of students’ understanding in six NOS aspects.

Table 2. A table showing the changes of the mean value of the results of the modified VNOS-D of the experimental and the control’s groups after the intervention

	”Empirical”	Role of Experiments.	Tentativeness	Subjectivity	Creative	Cultural
Experimental (n=76)	1.101	0.768	0.942	0.594	0.304	0.986
Control (n=40)	-0.056	0.028	0.222	0.222	0.472	-0.028

+ve = increment in NOS understanding
-ve = decrement in NOS understanding

There is a significant changes in NOS understanding in experimental group ($F(1, 67) = 165.165, p = .000$), while no significant changes is observed in the control class ($F(1, 31) = 3.701, p = .064$). That is an evidence that the intervention to promote NOS was effective.

From the subject test on scientific knowledge:

No significant changes in the students’ individual subject test score (normalized as represented by z-score) between pre- and post-test on subject knowledge, as there may be other reasons, besides improved NOS understanding, which affects students’ academic results. But the changes of their NOS understanding shows weak yet significant relationship with the changes of their subject test results ($r = .244, p = .018, n = 93$).

It is found that there is a weak correlation between students’ NOS understanding and their subject test (z-score) results, in both the pre-test ($r = .234, p = .023, n = 94$), and in the post-test ($r = .458, p = .000, n = 99$). It is supportive to the hypothesis that student’s academic performance is somehow related to their NOS understanding. It is noted that the correlation has become much stronger after the intervention.

Changes in students’ ATS

Changes of students’ attitude were calculated by the scores of the six dimensions of ATS. Table 3 below shows the changes of the attitudes of the students after the intervention:

Table 3. A table showing the changes of the mean value of the results of the ATSI of the experimental and the control's groups after the intervention.

	Perception of the teacher	Anxiety towards science	Value of science in society	Self concept of science	Enjoyment of science	Motivation in science
Experimental (n=76)	0.038	-0.098	0.053	-0.106	-0.092	-0.001
Control (n=40)	-0.033	-0.108	0.007	-0.087	-0.134	-0.004

+ve = increment in students' attitudes
-ve = decrement in students' attitudes

In the present study, analysis is mainly made to the dimensions of 'Value of science in society', 'Self concept of science', 'Enjoyment of science' and 'motivation in science', as they are directly related to the NOS themes covered in the intervention.

Both the experimental and the control group recorded an increment in their attitude towards the value of science in society, and the changes are significantly related to their NOS understanding (Both Groups: $r = .313, p = .002, n = 100$), which suggests that learning of NOS can help students to develop a more positive view towards the value of science in society. Although the relationship is observed before the intervention in the experimental group ($r = .242, p = .015, n = 100$), the relationship is becoming more significant after the intervention.

Significant drop ($F(1, 99) = 5.483, p = .021$) in self concept in both groups of students observed in the post test, with the experimental group (mean = -0.106) dropping to a greater degree than the control's (mean = -0.087), and the drop is significantly related to their changes in NOS understanding ($r = .259, p = .009, n = 100$). This maybe due to the fact that Asian students tend to be less confident in themselves when they learn more, as reported in TIMSS results in HK. (Martin, Mullis & Foy, 2008)

In the post-test, students' understanding on NOS are found to have a moderate co-relationship with their enjoyment in science ($r = .290, p = .003, n = 100$). There is a more significant drop in the control than in the experimental groups (Experimental group: $r = .329, p = .006, n = 68$; Control: $r = .464, p = .008, n = 32$). It may be possible that learning NOS is useful in slowing down the dying of students' interest towards science. As students were learning more concrete science from primary and S1, they might find the topics difficult and hence bored, e.g. electricity, which was consistent with the qualitative data from the interview.

Both the experimental and the control groups records decrements in their motivation in science after the intervention. However, the drop in the experimental group is significantly related to their NOS understanding ($r = .375, p = .002, n = 68$), but not that in the control group ($r = .092, p = .617, n = 32$). It is also known that the drop in their motivation is directly related to their changes in NOS understanding ($r = .311, p = .010, n = 68$), though there is no significant relationship between the controls' changes in NOS understanding with changes of motivation ($r = .061, p = .741, n = 32$).

From Interviews:

Students with notable changes in their attitudes between the pre- and post- test of ATSI are interviewed. The findings from the interviews are listed as follow:

Positive feelings about learning NOS

Sciences no longer facts to be memorized

Students reported that they found science more interesting. In the past scientific knowledge are facts to be studied by them, however, after learning about NOS, science was no longer sets of 'static facts' to be memorized: "(knowledge about NOS) can help inducing interest to investigate and learn science, as they show that science is not static. I thought that science was very boring because I viewed them as static facts in the past...". (NOS-1-35)

To know how the knowledge they are learning is generated

Learning NOS also helps them to have a clear picture of how scientific knowledge is generated, which motivates them to investigate on science. Students now reckoned learning about NOS is essential, as they think it is a must for them to understand what they are learning: "It is important to understand about science, as we should have the knowledge about what we are learning." (NOS-2-28)

Inspiring students to solve scientific problems in their everyday life

Learning NOS helps student to appreciate how scientists solved various scientific problems and generate scientific knowledge. This gives students faith in themselves for solving various problems like scientists do: "We (students) have the ability to solve problems by ourselves. Knowledge about science gives us the ability to do so." (NOS-1-37). Students reckon that, "It is a must for students to first understand about science, then they can be empowered to solve scientific problems by themselves when such problems arise. (Students) have the ability to solve problems by themselves. Knowledge about science gives (students) the ability to do so." (NOS-1-37)

Negative feelings about learning NOS

Some students did expressed some negative feelings towards learning NOS, as they found that "Boring, as it involves only abstract thinking, but no 'hands-on' work." Or, some of them found that NOS teachings are "A bit boring when it comes to history, ...the story is very long, but is in fact interesting if the conclusion is made known to the class immediately."

Other factors inducing changes in students' ATS

But it should be noted that different factors may affect students' ATS, and changes of their ATS might not be root from increased NOS knowledge alone. Other factors may also contribute to the positive changes. For example, students suggested that interesting practical works done in the year help them to have improved attitude towards science. Interesting practical works include ox's eye dissection, hydrogen test, testing pH, etc.. Some reported that the interesting content of the curriculum (e.g. space, acids/ base) also make them more interested in science.

Negative changes in students' ATS may also be contributed by other factors besides learning about NOS. Some students found the content of S2 curriculum quite difficult and boring (e.g. Electricity), which made them less interested in Science. Some couldn't understand the content of the experiments, while there were girls reported that they disliked calculations, and some whom obtained poor results in science, were all discouraged to develop a positive attitude towards science.

Conclusions and Implications

The present study showed that the intervention was useful in promoting learning of NOS, which led to significant changes in NOS understanding in experimental group.

The effect of learning of NOS on student's ATS was several-folded: Learning of NOS can help students to develop a more positive view towards the value of science, however, Asian students tend to be less confident in themselves when they learn more, and so gaining knowledge in NOS may lowered their self-concept. Learning about NOS may also be useful in slowing down the dying of students' interest and motivation towards science, when they encounter difficulties in their studies. This study also provides empirical evidence to show that there is a weak relationship between students' NOS understanding and their academic performance.

This study gives information from students' perspectives on learning about NOS: They reckon that it's good to know how scientific knowledge is generated, such that it motivate them to learn and investigate in science. However, in students' opinion it is essential to have a better balance between teaching NOS in class and having practical works in the lesson, that NOS teaching should not eat away time which was originally assigned for the practical works, which students are most interested in.

This study also provides support to the belief of science educators, that learning about NOS can make learning science more interesting, and may support their learning of science among some students. Suggestions raised by students can provide insights to teachers and curriculum developers for planning NOS lessons and curricula which better suit the needs of students.

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NATURE OF SCIENCE VERSUS NATURE OF ENGINEERING: FIRST-YEAR ENGINEERING STUDENTS' VIEWS OF SCIENCE AND ENGINEERING RELATIONS

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Abstract

Science and engineering are two fields to which we owe today's prosperity. But, people are often confused as to which field has contributed to an individual modern advancement. When researchers in science education discuss NOS, the focus is generally on the characteristics of science that make science unique among other disciplines such as philosophy, religion, or mathematics. Rarely do researchers ask: In what ways is science different from or similar to its companion; engineering? In order to fully grasp the meaning of NOS, individuals need to be able to differentiate science from engineering as well as see the close relationships between them. In this study, first-year engineering students' views of science and engineering relationships were investigated at the beginning of their first semester as college students. Although few participants perceived engineering as science, we found that most of the students view engineering as applied science in the sense that engineering uses scientific knowledge to accomplish the task at hand. Few students, however, demonstrated how products, devices or systems developed by engineers could help scientists study the nature of the world in which they conduct their research.

Introduction

Establishing a scientifically literate society is one of the main goals of science education. The Nature of Science (NOS) and the Nature of Technology (NOT) were placed as key components of scientific literacy in several national science education reform documents including Science for All Americans and National Science Standards (AAAS, 1989; NRC, 2000) because NOS/NOT help individuals understand capabilities, power, and effects of science and technology (ITEA, 2006, 2007). Moreover, an understanding of the NOS/NOT helps today's civilized societies make more informed decisions about developing and using new technologies more responsibly and rationally as well as evaluating the effects of technology on the environment and society (ITEA, 2007). However, teaching and learning of these phenomena might be challenging.

One of the challenges that science educators need to face is how to distinguish science from engineering. When former president Ronald Reagan was trying to promote a new generation of weapons that would improve the NATO's defense against long-range nuclear ballistic missiles, he called on the "scientific community" to help develop them, thereby confusing science and engineering as so many others do (Koen, 2003). There are obvious places where science and engineering overlap, but there are significant differences between these fields, as well. One of the important differences can be found in their knowledge claims: scientific knowledge claims are factual or

propositional, but in engineering they are procedural (Bucciarelli, 2003). Design and invention seems to be the main process of doing engineering work in order to satisfy a need or a desire in engineering (Dym, 1999; Petroski, 1985; Wulf, 2002) whereas constructing theories in order to predict or explain phenomena is one of the main purposes of science (Kuhn, 1996). Another difference between science and engineering involves their ontological approaches: engineering is non-dualist and (neither realist nor relativist towards knowledge claims, but rather) pragmatic. Thus, Kuhn's assertion of incommensurability of paradigms in science may not be applicable to engineering (Kuhn, 1996). There are many other differences between science and engineering (see Table 1). However, there are many similarities between them too. One of the similarities between the two disciplines is the role that creativity plays, others include the theory-laden aspect of innovations and discoveries or inventions, the tendency for knowledge and solutions to be tentative, and the social and culture embeddedness of the two fields (Lewin, 1983; Bucciarelli, 2003; Finch, 1960; Petroski, 1985; Rogers, 1983). We suspect that these similarities might be the sources of individuals' confusion of science and engineering.

Table 1. Comparison of engineering and science from several standpoints

Points of Comparison	Engineering	Science
Knowledge claims	Procedural knowledge – <i>know how</i>	“factual-propositional” knowledge – <i>know that</i>
Aims	Change nature for needs and desires	Understand the natural world
Process	Design systems and artifacts that work under certain constraints	Construct theories that predict and/or explain
Progress	Evolutionary and revolutionary	Articulation within paradigm and revolutionary
Criteria for the best design/theory	Context dependent, sustainable, robust, economical, minimal side effects	Better explanatory of the related phenomenon Open-ended: more predictive power
Role of failures	Determine limits of the design Improvement in design	Determine limits of the theory: modifications in theory, anomalies may lead crisis/revolutions
The ontological status of scientific knowledge claims	In engineering: Pragmatic: non-dualist	“truth” is defined with the eyes of the current paradigm
Validation of design/knowledge claims	Regulations, community acceptance (engineering firm and also client), cost-benefit, marketing success/acceptance	Community acceptance (scientific community)

Rationale

The key part of the research that has been done on NOS is discovering what makes science unique or how it is different from other fields of study (e.g. art, philosophy, religion). Even though this is the key component of the nature of science education, science and engineering are rarely placed in a compare/contrast situation because of the close relationship between the two. However, it is clear that science and engineering are confused by vast majority of the society (Karatas et al., 2008; Koen, 2003). We believe that without differentiating science from engineering, it might be hard to grasp the NOS. Therefore, in order to fully understand the NOS, students should be able to differentiate it from engineering. In this study, we investigated first-year engineering students' views of science and how they distinguished science from engineering. First-year engineering students take as many science courses at both the K-12 level and first-year college or university level as first-year college science students, but they have special interest towards engineering. This variant led us to believe that this study would be very beneficial.

Methods

A qualitative research method was adopted in the process of this study. Phenomenography was chosen as guiding theoretical framework (Marton, 1994). The goal of this approach in educational research is to define the different ways in which people experience, interpret, understand, perceive, and conceptualize a phenomenon, or certain aspects of reality (Marton, 1986). Because the main results of phenomenographic research are categories of description of the various conceptions of a phenomenon, we carried out inductive analysis to analyze the data (Patton, 2002).

The participants consisted of two separate cohorts. The first cohort comprises of 114 participants who were selected by applying a mixture of non-proportional stratified sampling and maximum variation sampling based on their ethnicity and gender to ensure a large span of variance in beliefs from a pool of 838 first-year engineering students who enrolled in ENGR 126 course during the fall 2007. The second cohort was recruited in following year from the students who enrolled in ENGR 12600 course which was the same course as ENGR 126 with a different code due to university-wide course code change.

Questionnaire

A 12-item open-ended questionnaire was administered in order to collect the data about students' views of the nature of engineering (NOE). However, only the results of the data from three questions that are related to our current topic are discussed. These questions are:

1. Do you agree with the statement that “engineering is applied science? Why, or why not?”
2. In what ways are science and engineering similar?
3. What are the differences between science and engineering?

The questionnaire was employed at the beginning of the semester in order to probe students' views before they become immersed in the engineering program. Administration of the questions was completed electronically. Student had to sign in ENGR 126 course website, fill out the questions, and then submit their responses.

Interviews

Semi-structured interviews were developed based on the questionnaire in order to increase confidence in the findings and greater understanding of students' views of the relationship between engineering and science. All of the second cohort students were interviewed. During the interviews, the researcher prompted sub-questions to clarify the participants' views in this issue. All interviews were audio-taped and transcribed verbatim.

Qualitative Analysis

Students' responses from the questionnaire and interviews were analyzed by identifying qualitatively distinct categories in order to demonstrate different ways of viewing the relationship between engineering and science. The analysis process began with organizing the data. The next step was open coding, a form of inductive data analysis (Patton, 2002). These codes were then analyzed more in depth by looking for similarities and differences among the codes. This process was repeated in order to develop as few general categories as possible to describe the participants' views. The data analysis was done by the first author and results were then discussed with the second author, to check for consistency in coding.

Results

The relationship between science and engineering

An outcome space based on the students' responses was developed and organized in a hierarchical order in terms of the complexity of the distinction between science and engineering (see Table 2). In Table 2, numbers of students' responses to the questionnaire were sorted by each category. Quotes were taken both from the questionnaires and interviews. As seen in Table 2, few students believed that engineering is a field of science, that science is an overarching concept that includes engineering, or that science is engineering. Many students, on the other hand, stated that engineering is applied science. Some students indicated that science provides background knowledge for engineering. This category is slightly different from the previous category "engineering as applied science" because students' responses in the higher category highlighted science as a necessity or requirement for engineering, akin to a tool. Whereas for the responses in the "engineering as applied science" category engineering was seen as successor of science as if there was an organic and direct relationship between the fields and people who work in these fields. "Science discovers and engineering creates" is another category that included students' responses in which a clear and distinct comparison was made between the two fields. Students in this category either indicated that engineering is science or applied science or stated scientific knowledge is a tool for engineering. The responses that were collected in the last category not only indicate that engineering and science are two distinct fields, but they rely on each other rather than emphasizing only one aspect of the relationship between these fields (e. g. scientific knowledge is used in engineering).

Analysis of interview transcripts revealed similar categories of description regarding the relationship between science and engineering. However, a few of the interviewees were unable to form any kind of relationship between science and engineering even though they tried to describe each field separately. For example, Tim was puzzled when trying to describe the differences between science and engineering.

F: What is the difference between them?

Tim: Umm... I fell like... engineers... umm... I don't know... engineers kind of like... I don't know. I mean I know they're similar, but I don't know what like what makes them totally like different. Like what makes them...

...

Tim: Umm... I don't know. I was thinking like chemical engineering and stuff like that because what I wanna be is a chemical engineer. But, I don't know that is what I think of like scientist and engineering just like...

F: So, that is a good point, so there is a chemist or chemistry and also chemical engineering and chemical engineer right?

Tim: Uhum.

F: So, how are those similar or how... what do you think a chemist does and a chemical engineer does?

Tim: Umm... chemical engineers kind of like...

F: I don't want to be you know too specific because you're at the beginning of the program. So, but... in a general sense how do you think they're similar or different?

Tim: Engineers and scientist?

F: Yeah, I mean if you want to focus on chemistry that is ok.

Tim: I don't know...

Table 2. Students' views of the relationship between science and engineering

Category (N)	Student quote
Engineering as a science field (N=11)	“Engineering is a form of science.” “Science is engineering. There are no differences.”
Engineering as applied science (N=8)	“Engineering is an application of science. Both work on the same principles that govern the physical world.” “Differences between science and engineering is the application of science that is engineering, when science is more theoretical than applied in the real world.”
Science as background knowledge for engineering (N=19)	“They are similar because engineering is linked together with science, physics and chemistry are used by engineers everyday” “Science is the fundamental of engineering. Only through science is that one understands the way the world works in order to one achieves. It deals with all of the basic principles that an engineer works through.”
Science discovers, engineering creates or applies (N=35)	“Scientists try to understand nature, and engineers try to create things that don't exist in nature.” “Instead of thinking, "why is that?", engineers think, "how can I use that?"”
Engineering and science as distinct fields, but complementary (N=13)	“Nowadays, science cannot move further without the help of engineering. Engineering also cannot move forward without the help of science. They are both needed together and cannot exist without the other.”

Similarities between science and engineering

The interviews were primarily focused on the relationship between science and engineering and the differences between them. Therefore, students' responses to the questionnaire questions were the main source of data that revealed three main similarities between science and engineering that students held: a) purposes, b) processes and methods, and c) sources and tools. According to some students, purposes of engineering and science include solving problems. But, students did not make any distinction of the nature of problems in science and engineering, except for one interviewee. Spike indicated that engineers are given problems whereas scientists “come up with” the problems.

Spike: Umm... purpose of science would be... similar to purpose of technology and that or I mean purpose of engineering and that it comes up with solutions to problems. But, it does so and a much different view.

Researcher: What is that different view?

Spike: Science would come up to... science comes up with solutions to the problem umm... that are... that scientist themselves come up with in lab or a lab environment whereas umm... engineers would come up with umm... solutions to problems that are presented to them either by an employer or by umm... this... the environment or situation.

Advancing by making life and things easier and more efficient was cited by nine students. Another five students mentioned that developing products to meet the need of the people as common goal of engineering and science. Developing products to meet or satisfy a need or advancing by technology has been attributed to engineering rather than science by scholars (Dym, 1994; NAE, 2004).

They are similar in which both want to make the world more advanced in technology.

Science and engineering are both based on progression. They are both used to help make things better and more efficient.

On the other hand, five students' responses in the questionnaire focused on understanding the world as another similarity between these fields. It seems that these students were confused about science and engineering (Kang et al, 2005; Stein & McRobbie, 1997).

Students who claimed process or methods of engineering and science are similar (N=20) indicated that both fields follow a certain method and involve experimenting, testing, analysis, and observation. A typical student response in this category is:

They both have a defined process for coming to a solution, and both are constantly checking to make sure that they are correct.

The last category that describes students' views of the similarities between the two fields includes background knowledge, tools, and technology. Ten students in the questionnaire, for example, indicated that both fields utilize mathematics. Nine others claimed that both engineering and science use same or similar background knowledge, principles, or technology. A few students focused on intellectual requirements and stated that logical thinking a shared necessity for the both. Consider following quotes as illustrations of students' views in this category.

They use the same principles to solve problems

They both take from the same principles and ideas

The "myths" about science

In addition to the relationship between science and engineering, students' responses revealed a few "myths" that they believed about the nature of science. Thankfully, these myths were not very common. A few notable beliefs are included: There is no invention in science and scientific process is straightforward; science is about methods, theories and laws of the world, and mechanics; science is laboratory based and experimental; and "science merely pursues knowledge. Engineering pursues knowledge and the use thereof."

A few students especially in interviews believed that the scope of science covers discovering everything. Sean, for example, claimed that English is a science:

R: OK. What is the purpose of science?

Sean: Discovery...

R: Discovery of what?

Sean: Everything!

R: Everything you mean?

Sean: Science's like discovering everything around you. Like, I think of English as the science of communication.

Conclusions and Implications

Even though more than half of the students indicated that the intent of science was to discover things and engineering's intent was mostly to apply these facts, and/or methods; only a few students mentioned how engineering affects science. Besides a naïve image of science in individuals' minds, many characteristics of engineering were attributed to science and/or vice versa. Although only a small number of the participants believed that engineering is a science field, many students agreed with the statement that "engineering is applied science." Their explanations were more likely utilizing science to do engineering. However, only a few students explicitly indicated that the application of scientific knowledge was only one aspect of engineering. This means that even though students do not hold a solid traditional view of engineering which is "applied science," they could not distinguish "applied science" from engineering either. Students failed to differentiate the scope and dimensions of

each field. We believe that some understanding of the nature of engineering should be integrated in today's K-12 science teaching efforts as another dimension of nature of science. Contrary to current practice of focusing on technology and its relation to science, developmental stages and associated values of technology should be the focus by comparing these entities with scientific inquiry. By doing this, we believe that it would increase students' knowledge and awareness of the NOS and the NOE which might affect students to make more informed decisions for their future career.

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ELEMENTARY SCHOOL STUDENTS' PERCEPTIONS ABOUT SCIENTISTS

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Abstract

Research performed for over 50 years reveal that an image of scientist has emerged in students' minds. The purpose of this research is, to determine the elementary school first phase students' perceptions about scientists, to inspect the change of student perceptions relative to the grade of the students and to inspect the change of perception of students from different schools out of different socio-economical environment. A sum of 152 students from 1st, 2nd, 3rd, 4th and 5th grades participated in the research. Ideas about scientists in students' minds are tried to be revealed using drawing technique. In this context, students are asked to draw a picture of a scientist. A checklist, consisting of "Drawn a Scientist Test – Checklist DAST-C" introduced by Finson, Beaver and Cramond (1995) and some additional elements to the original checklist, was used in the evaluation process of the drawings. Research results prove that "scientist image" of students have differences in several aspects in comparison to the earlier studies. For example, images of casually dressed, collaborating scientists with a happy look in the face are significant among others. In addition, most of the drawings picture male scientists with eye glasses and laboratory coats which are identical to the previous studies.

Introduction

Science has different definitions in different resources. In Active Study Dictionary of English, the word "science" has three definitions. These definitions are as follows: 1- Knowledge which depends on testing facts and stating general natural laws, or the study which produces this knowledge. 2- A branch of such knowledge, such as chemistry. 3- Something that needs exact skill. Science is the sum of efforts that has been found as the result of applications of tools, instruments and technology which makes our work easier, allows us recognize environment better and grants us opportunity for a better health and longer life (Ortaş, 2002). Science is sum of robust objective information, accumulation of systematic knowledge in which cause-result relations are defined, sum of proven and recorded knowledge that humankind accumulated (Yaşar, 1998). Science is the effort of humankind to understand and explain the physical universe (Türkmen, 2006). When the different definitions of science are inspected, we come across some common concepts. These concepts are as follows: Effort (to understand the environment we live in), collection of systematic knowledge and process. The variation of the definition of science can be explained with the dynamic structure of the science (Türkmen, 2006). Therefore, science is a rapidly developing activity. Similar to the question of "what is science", the question of "who is a scientist" has no exact and static answer. Some of the answers to this question are as follows:

A scientist is: A person who runs intellectual and factual processes in compliance to scientific method (Ortaş,2002).

A person, who inspects the events and facts of the universe, investigates the mysteries underlying them and tries to understand the reasons of those mysteries, simplifies the understanding he gathered throughout the process in order to make the large communities gain the knowledge s/he discovered, and announces it (Yaşar, 1998).

Although we come across many different definitions of scientist in resources, common properties of scientist are listed as follows (Yapıcı, 2005).

- Scientist should be objective while interpreting the information he gained using scientific methods.
- Scientist should be aware that s/he should be skeptical about all information.
- Scientist should observe his environment in a critical manner.
- Scientist should be aware of his social responsibility

There exists a bi-directional relationship among the concepts of science, technology, society and education. Scientist plays an important role in these relations. Technology is a design-produce process that begins with human needs. In this process, scientific information, raw material and energy are used as inputs in order to make a consumable product. It also affects society as well as becomes affected by social norms and merits. Especially in today's world, scientific information is converted to technology in great volume which cannot be compared to past periods. This fast interaction between science and technology affects the lives of societies and education of individuals (Uluğ, 1997).

There is a good chance of being a scientist for individuals who belong to a society which had a good education of science. For other individuals of such a society, who are no scientists, there is thought to be a good chance of growing up as individuals who esteem scientific studies and technologic developments (MEB, 2005). The most important thing is obtaining the highest level of benefit from this interaction.

Considering the relation between science, technology, society and education, the opinions of the children about scientist, which is the subject of science, can be regarded as a factor which is able to affect the point of view of the society in the future. In this aspect, defining the sentiments of elementary school students' sentiments about scientist is important.

Rationale

According to Petkove (1994), determination of the opinions of students about scientist is not just curiosity. The important things are, making scientific activity familiar and make society understand science (Quated by; Schibeci ,2006).

The opinions of students about scientists are also important because they might be indicators of their tendency to science and their possible future higher education in scientific field (Yvonne, 2002). Because of the constantly growing needs, it is aimed to grow up technology literate students for the society. If we need to grow up students who can understand science and scientist, we should know of their opinions on science and scientist first (MEB, 2005; Yaşar, 1998).

It is thought that students who face right information about science and scientist at the first years of the elementary school will respect scientists and their work when they become individuals serving the community in different areas in the future (Yurdakul, 2005). In this context, defining the opinions of elementary school first phase students about scientist will contribute to the literature.

Purpose

This study has been performed in order to inspect;

- The opinions of students about scientist,
- The change of the opinions of students about scientist according to grade levels,
- The change of the opinions of students about scientist according to socio-economic levels.

Methods

152 elementary school students participated in the study ranging from 1st to 5th grades. Research has been performed in two schools, one of which is a public school and the other is a private school. Public school (71 students) is placed in a socio-economically low-level area of the city, where the attendants of the private school (81 students) belong to families which constitute the socio-culturally higher level of the society. Study is performed during spring semester of 2007-2008 educational years. Distribution of the students according to grade levels and school types are presented in Table 1.

Table 1. Distribution of the students according to grade levels and school types.

School Type	1 st Grade	2 nd Grade	3 rd Grade	4 th Grade	5 th Grade
Private School	17	16	9	20	19
Public School	14	11	10	18	18
Total	31	27	19	38	37

In this research, survey method is utilized. Survey model is referred as “area research method” or “field research” in the literature. Researcher who uses survey model for his research aims to reveal the characteristics of the individuals in his research area realistically (Arseven, 2001). In order to figure out the student sentiments about scientist, DAST (Draw a Scientist Test), formed by Chambers in 1953, is used. Since Turkish word “bilim adamı” for scientist carried out a male meaning, another word “bilim insanı”, which resembled no gender, is used in the directive of “draw a scientist” to avoid the students make male scientist drawings at all. No other explanation is given to the students in order not to affect them. Students were allowed to make extra drawings in multiple pages. They are also informed that they were allowed to write down short noted on their drawings about the figures in order not to experience problems during the evaluation phase. Enhancing the reliability of the research is aimed by this way.

In literature survey, several different instruments are found to have been used in determining the opinions of students about scientist as tools of data acquisition Researchers decided that DAST would be the best fitting instrument for data acquisition considering the properties of the participant students and grade levels.

Since DAST is an acquisition tool used in determining the behavior rather that evaluating the behavior, it is proper for building up hypothesis about student sentiments. In addition, short application duration for DAST (application lasted approximately 20 minutes) complied to the attention duration of the survey group (Öcal, 2007).

DAST is a drawing test used for acquiring the sentiments of students about scientist. In this test, students are asked to make a drawing of a scientist. The drawings are evaluated using a checklist called DAST-C. Chambers has worked with 4807 students from 5 to 11 ages in order to develop DAST from 1966 to 1977. At the end of the study, seven common properties of scientist were identified. The checklist, in which these seven properties existed, is named as DAST-C. These properties are as follows: Laboratory Coat, Eye-glasses, Technologic instruments, Formulas, Bald, Untidy Hair, Beard (Chambers 1983).

Drawings acquired by DAST were inspected by three researchers. At the end of inspection, a new control list was formed by appending new sections and subsections to DAST-C (Draw a Scientist Test Check List) (Table.2). Drawings were evaluated according to the new control list.

Table 2. The control list used in data analysis

Drawing Elements	Sub elements
Outfit Properties	Laboratory Coat
	Suit
	Casual
Drawing at the head sector	Not specified
	Untidy haired
	Combed haired
	Bald
Symbol of knowledge	Beard
	Book/Notebook
	Pencil
	Paper
	Computer
Figures accompanying The Scientist	No symbol of knowledge
	Human
	Animal
	Plant
	Experiment tools
	Telephone
	Telescope
	Robot
No drawings	
Gender	Male
	Female
	Not specified
Working Environment	Laboratory
	Office
	Home
	Forest
	Space
	Not specified
Facial expression	Happy
	Angry
	Grumpy
	Sad
	Worried
	Not clear/ Uncertain
Accessories	Eye glasses
	Hat
	Necklace/Ear
	Rings/Belt/Tie/
	Collar Handkerchief
	Badge/Cloak/Scarf
	Not specified.

Results and Discussion

Drawings acquired by DAST were evaluated according to the new control list which is formed by adding new sections and subsections to DAST-C and revealed following interesting results.

Conclusions about the outfit properties are figure of scientist with casual outfit is the most drawn figure at all grade levels. This conclusion is important because it shows us that the cliché opinion of laboratory-coat-wearing-scientist determined in Öcal 2007, Güler&Akman 2007, Muşlu&Akgül 2006, Flick 1990, Chambers 1983 and Mead&Metraux 1957 is losing ground.

Another interesting result of the research is, all of the public school 2nd grade students have drawn casual wearing scientist. Casual-outfitted-scientist shares the highest drawing percentage with suit-wearing-scientist in special school 3rd grade students' drawings where it shares the same with laboratory-coat-wearing-scientist in special school 5th grade students. At all grade levels, public school students are found to be drawing casual-outfitted-scientist with a higher percentage than special school students.

Top two figures for drawings near head section are untidy-haired scientist and combed-haired scientist. This result is important because it shows us that the cliché opinions of untidy-haired-scientist of Yvonne (2002), Güler&Akman (2006), Finson (2002) is beginning to change. For instance, first grade students from both schools have drawn untidy-haired-scientist with highest percentage. In addition, special school 2nd grade students have drawn combed-haired-scientist with highest percentage (50%). Public school students illustrated untidy-haired-scientist with highest percentage (66.6%). Only 4th and 5th grade students have drawn bearded scientists. No significant relation is found between grade levels and drawing properties.

For symbol of knowledge category, drawings with no symbols of knowledge and drawings with book/notebook as a symbol of knowledge has the highest percentages. No significant relation is found between grade levels and drawing properties. An important point is the drawings from private school students have the highest percentage of drawings with no symbol of knowledge. All 2nd and 4th grade students from public school has drawn book/notebook with the highest percentages, 45.4% and 66.6% respectively. For the students from special school, drawings bearing no symbol of knowledge has the highest percentage (77.7% in 4th graders for instance).

For the figures accompanying the scientist, the ones with the highest percentage are drawings with experimental tools, drawings with humans and drawings with no other figures. The most interesting thing is that in a very high percentage students have drawn people next to the scientist. This is an indicator of change of the opinions in "scientist is asocial" of Yvonne (2002), Rampal (1992) and Chambers (1983). In addition, even in low percentages there are drawings of plants, animals and telescopes. This may be considered as an indicator of change in the opinions of "scientist experiments in laboratory", which is stated in Schibeci & Sorenson (1983) and Mead & Metraux (1957).

For all grade levels, male scientist has the highest ratio. But female scientist drawings (special school 1st graders 35.2%, public school 1st graders 35.7%) we come into at all grade levels indicate that dominant opinion of "scientist is male" in Muşlu & Akgül (2006), Yvonne (2002), Chambers (1983) and Mead & Metraux (1957) is changing.

In the working environment category, laboratory and no-environment specified drawings score the highest percentage. Important facts are, laboratory has the highest ratio of drawing only in 3 classes (special school 1st graders 58.8%, 3rd graders 33.3%, 4th graders 75%) and even in low percentages, there existed drawings of home or forest. This is a strong indicator of change in the opinion of "scientist experiments in laboratory", which is strongly emphasized in Muşlu & Akgül (2006), Chambers /1983), Schibeci & Sorenson (1983) and Mead & Metraux (1957). Another interesting result of the research is, all public school 1st grade students made drawings which resembled no environmental property.

For most grade levels, a happy scientist is drawn at highest percentage. Two whole classes (2nd and 3rd grades) from the public school drawing a happy scientist figure is an interesting finding we came across. Even in different and low percentages, angry, thoughtful, grumpy, sad or emotionless face drawings has been made.

Students made accessory drawings at different percentages. Eye glasses wearing scientist figure was drawn at highest percentage only in one class. This is a token of a change of the scientist-with-eye-glasses cliché which we see in the studies of Güler & Akman (2006), Yvonne (2002), Finson (2002) Chambers (1983), Schibeci & Sorenson (1983), and Mead & Metraux (1957).

Conclusions and Implications

Research conclusions revealed that the opinions of the participant students began to differ from the cliché student opinions about scientist defined by past studies. It is possible to state that students' opinions change slightly in several sections and subsections of the control list according to grade level and socio-economical level of the student. Implications which are thought to make students have correct and positive opinions about scientist are as follows:

- Students may be encouraged to read books and periodic publications about science and scientist by teachers and parents.
- Up-to-date information about science, scientist and science-technology-society may be represented on the bulletins, called “scientific news”, formed in classes.
- Science festivals may be organized, to which students can contribute with different activities or projects, in order to show students that science can be performed at all ages and in different environments.
- Tours may be organized which might allow students see the scientist's working environment.
- Cartoons about science, scientist, science and technology may be produced.

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A STUDY OF STUDENT BELIEFS ABOUT THE EPISTEMOLOGY OF SCIENCE AND THEIR RELATIONSHIP WITH STUDENTS' PERSONAL EPISTEMOLOGIES

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Abstract

A recent trend in the teaching of science has been to place greater emphasis on teaching about the nature of science or how science works. One of the goals of this emphasis has been to improve students' knowledge and understanding of the epistemology of science. More recently another body of research has begun to explore and measure students' personal epistemologies. The research presented in this paper sought to explore the extent to which students' epistemic beliefs and their personal epistemologies were related using a sample of 480, year 8 and year 10 UK students. Students' beliefs about the nature of science were measured using both a questionnaire and interview-based study with instruments adapted from previous research. Their personal epistemic beliefs were assessed using an instrument developed by Deanna Kubn and her co-workers. Quantitative data were analysed using SPSS and the qualitative data from the interviews coded and analysed for their principle themes using NVivo. The findings fill a gap in the literature offering some insights into the relationship between these two constructs suggesting that students' personal epistemologies are more sophisticated than their understanding of the epistemology of science. The implications for the teaching of science are explored.

Introduction

The rationality of science is based on a central commitment to evidence as the basis of belief (Siegel, 1989). A reasonable expectation might be, therefore, that an education in science would develop students' understanding of the *epistemology of science* as it will expose them to the basis of scientific reasoning and its value. As a corollary, such an understanding might help develop their own *personal epistemology* – that is the criteria that students use for judging the

value of knowledge claims. Kuhn and her co-workers, for instance, argue that, on a personal level, students need to acquire a personal epistemology which she characterizes as that of an 'evaluativist'. Such individuals are able to identify and distinguish theoretical claims from the evidence used to support them; recognise claims as potentially falsifiable; and see evidence as the means of falsification (Kuhn, Iordanou, Pease, & Wirkala, 2008). These are the elements of rational thought and such meta-knowledge is the essential foundation of skilled scientific thinking and reasoning. But what is known about students' understanding of the epistemology of science and their own personal epistemologies?

Rationale

Research on students' understanding of the epistemology of science itself (as opposed to their personal epistemology) has suggested that students' knowledge and understanding is fairly limited (Driver, et al., 1996; Sandoval, 2003). Driver et al. concluded that students have difficulty determining the role of theories in science and the way that theories are evaluated against existing data by experimentation. In particular, scientific theories were viewed as simple descriptions of taken-for-granted facts, especially for 9-year olds. Moreover for these students, theories were seen to be of lower epistemic status than 'facts' which were considered to be the ultimate goal of science. Such a finding stands in stark contrast to the view *within* science that 'theories are the crown of science, for in them our understanding of the world is expressed' (Harré, 1984, p. 168). Views of scientific theories as ideas based in evidence, or as a way of modeling phenomena and predicting their behavior, were found more often in older students' responses. Sandoval and Morrison (2003) have also explored high school students' ideas of scientific theories and theory change finding: a) that scientific theories were viewed as hypotheses which are repeatedly proven; and b) the dominance of a correspondence view of science where scientific theories are thought to provide explanations of the world as it is rather than being a map of reality which has the potential to be improved.

Looked somewhat more broadly from a domain-general perspective, Hofer and Pintrich (1997) have suggested that there are four dimensions to any individuals' epistemological beliefs. These are: certainty of knowledge (stability); simplicity of knowledge (structure); source of knowing (authority); and justification for knowing (evaluation of knowledge claims).

Certainty of knowledge is something which changes over time beginning at lower levels where knowledge is certain and absolute and moving to a view where knowledge is seen as tentative and evolving and where individuals are open to new interpretations. Simplicity of knowledge is a measure of an individual's understanding of the structure of knowledge and lies on a continuum between an accumulation of facts versus a set of highly inter-related concepts. The lower-level view is to see knowledge as a set of discrete facts whilst at the higher level knowledge becomes relative and contextual and open to interpretation. Source of knowing refers to views an individual holds about the source of epistemic authority. At lower levels it originates outside the self and resides in an external authority. The big transformation comes when the individual who was previously 'a holder of meaning becomes a maker of meaning' (Perry, 1970, p. 87) and recognizes that transformation. Justification of knowing refers to the views that individuals hold about how claims to knowledge can be justified moving from dualistic beliefs where ideas are either right or wrong to an understanding that knowledge is something which requires a reasoned justification for belief.

To measure these concepts, an instrument was initially developed by Elder (2002) and then improved by Conley et al. (2004), who showed it to be internally reliable and hold a four-dimensional factor structure corresponding to these theoretical scales using confirmatory factor analysis. Data gathered from a sample of 187, fifth grade students, showed that students became more sophisticated in their beliefs about the source and certainty of knowledge with instruction, but that there were no reliable changes in justification.

Students' personal epistemologies, in contrast, are the means or approaches that students use for judging and evaluating claims about knowledge that they meet within their own lives – what Sandoval terms 'practical epistemologies' which he distinguishes from 'formal epistemologies' which are the ideas they hold about scientific reasoning. The latter, he argues, are hopelessly naïve (Sandoval, 2005). When it comes to assessing students' personal (or practical) epistemologies, Kuhn and her co-workers (Kuhn, 1999; Kuhn et al., 2000) have argued for a developmental model of students' personal epistemologies proposing that students begin life as 'absolutists' where knowledge consists of certain unequivocal facts. From here, students are thought to progress to becoming essentially relativists. This occurs when they begin to recognize that there is a subjective element to knowledge and lack any sense that there are criteria that enable some claims to be judged more valid than others. These individuals she terms 'multiplists'. The final stage is when students become 'evaluativists' and recognize that there is a need to evaluate critically the evidence provided to support claims to knowledge.

The question of interest for this research is to what extent are students' personal epistemologies related to their 'formal' epistemologies? To date, researchers in science education have seen students' personal epistemologies as only tangentially related to the central epistemological questions of science that seek to explain how we know (Kuhn et al., 2008). However, their inter-relatedness is a concern for science educators. Ford (2008), for instance, argues that the predominant emphasis within science on the construction of scientific knowledge and understanding is misplaced. Rather, students need an opportunity to engage in the evaluation and critical review of knowledge claims. Such skills he sees as 'crucial resources to learning novel scientific ideas with understanding' (p. 405). Only through engaging in the interplay between construction and critique which is the hallmark of scientific thinking will students:

come to *know that* scientific knowledge is held accountable by explicit connections to nature, to *know how* to play the roles of constructor and critiquer appropriately, and to *know that* the interaction of these roles in practice yields reliable knowledge. (p.405, author's emphasis)

Moreover, if students' personal epistemologies are generally more sophisticated than their formal understanding of scientific epistemology it would suggest that their education in science has done little to capitalize on their epistemic potential. More worryingly, the presentation, either implicitly or explicitly within the context of school science of a naïve epistemology could be hindering the development of students' personal epistemology.

The interrelationship between students' formal epistemology and their practical epistemologies is a focus, at least in part, of the research we are conducting for the funded project 'Talking to Learn, Learning to Talk in Science'. The primary goal is twofold. First to see whether working with schools rather than individuals would help to establish a professional learning community where the use of argumentation and a dialogic pedagogy would become a more established feature of teachers' pedagogic practice. Second, we sought to see what effect it would have on students' cognition, their understanding of the nature of science and their epistemic beliefs. To answer the latter question we have drawn on the work of Kuhn et al. to assess student's practical epistemologies, the work of Conley et al. to assess students' epistemological beliefs, and the work of Driver et al. (1996) to assess both. Our goal is based on an argument that this data may help to fill this lacuna in the literature and to answer the question of what is the relationship, if any, between students' knowledge of the epistemology of science and their personal epistemic beliefs. The central question of interest here being one of whether a better understanding of the epistemology of science is associated with a more sophisticated personal epistemology?

Methods and Design

For this work, 9 schools were recruited from the Greater London area (4 for the intervention and 5 to act as controls). The sample was purposive in that schools were selected to represent a range of socio-economic conditions. From each school, two classes of Year 7 and two classes of Year 9 students were selected for testing. Thus the sample consists of approximately 480, Grade 7 students and 480, Year 9 students. Students'

epistemological beliefs were measured using a survey instrument developed from the items used by Conley et al. (2004) whilst their personal epistemic beliefs were measured using a version of the instrument developed by Kuhn et al. (1999). The items from Conley et al. use a 5 point Likert scale, which has been previously validated, whilst those of Kuhn et al. pose a set of alternative judgements about knowledge claims and students have to judge which they consider to be ‘true’. The nature of their response to these items and its consistency enables a judgement to be made as to whether they are epistemological absolutists, multiplists or evaluativists. The data from these instruments were analyzed using SPSS.

Students’ understanding of the relationship between theories and evidence and the relative epistemic status of facts, theories and hypotheses was also measured by conducting 20 minute interviews with 6 pairs of students in each grade, providing a sample of 48 pairs in each year, and using an adapted form of the instruments developed by Driver et al. (1996). These interviews provide data both about their practical epistemology that they deploy when confronted with the need to resolve conflicting evidence and their views about the nature of knowledge in science i.e. their formal epistemology. The rationale for using group interviews was that the opportunity for students to engage in discursive interaction with each other would produce more insights into student thinking and that this would be less intimidating – particularly for younger students. This does mean, however, that the unit of analysis becomes the group and not the individual. Thus in coming to a view about the meaning of the discourse, it was always the outcome of any student discussion that was coded rather than individual difference. Data from the interviews were analyzed using a coding schema which was in part grounded in the data (Strauss & Corbin, 1994) and in part driven by contemporary theoretical frameworks of what constitutes a sophisticated scientific epistemology (Hodson, 2008; Longino, 1990; Pickering, 1995). For instance, a particular interest was in how they saw the interrelationship between facts and theories. Using the schema, the interviews were coded and cross-checks conducted for reliability between three researchers. Agreement in excess of 70% was deemed acceptable. Interviews were then coded using NVivo 8 to identify the major features in student understanding.

Results

Data from the Kuhn Instrument was categorised using their responses into a set of categories which were:

Absolutist:	3 Absolutist Responses
Absolutist/Multiplist:	A mix of absolutist and multiplist responses
Multiplist	3 Multiplist responses
Evaluativist-	2 Evaluativist responses and another response which was either absolutist or multiplist
Evaluativist	3 Evaluativist responses
Indeterminate	One response of each type

The distribution of responses and their percentages by year group are shown in Table 1 and Fig 1 and Fig 2.

Table 1. Table showing the percentage of students and their epistemological levels.

Epistemological Level	Details	Year 7 %	Year 9 %
Absolutist		1.9	0.9
Absolutist+	2 Abs & 1 Multiplist 1 Abs & 2 Multiplist	8.9	8.4
Multiplist		3.7	6.5
Evaluativist-	2 Evaluativist + 1 Absolutist/Multiplist	39.6	36.7
Evaluativist		39.2	42.1
Indeterminate		6.8	5.3

These responses show that the practical epistemology of most students can be assessed as evaluativists or near to that. Granted the assessment is made on a very limited number of items, which would suggest that the data are an indication of how students reason rather than a consistent reliable measure. These data are triangulated, therefore, against other data which we discuss beneath.

Year 7

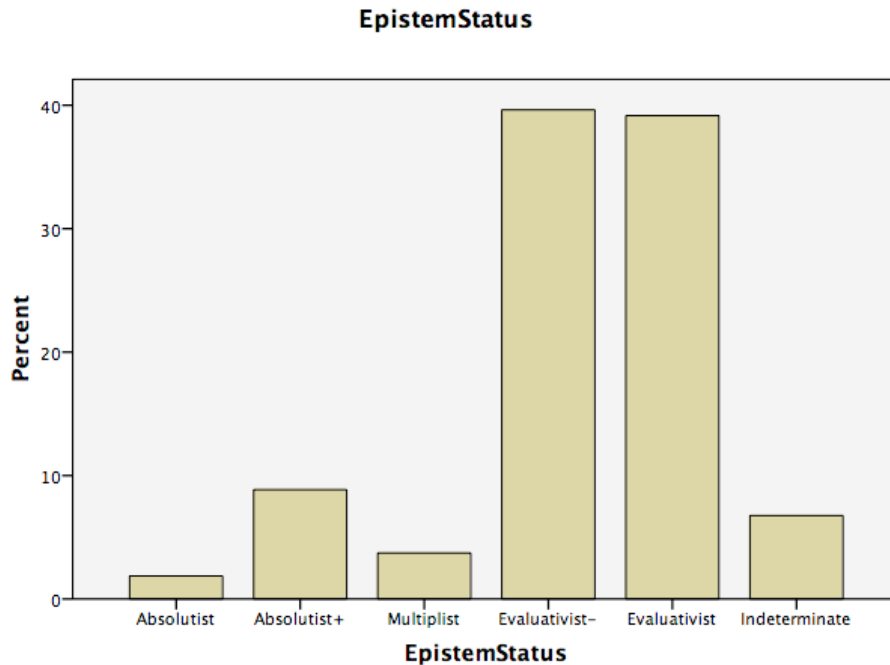


Figure 1. Chart showing Distribution of Personal Epistemologies from the Kuhn Instrument and the Year 7 sample (n=429).

Year 9

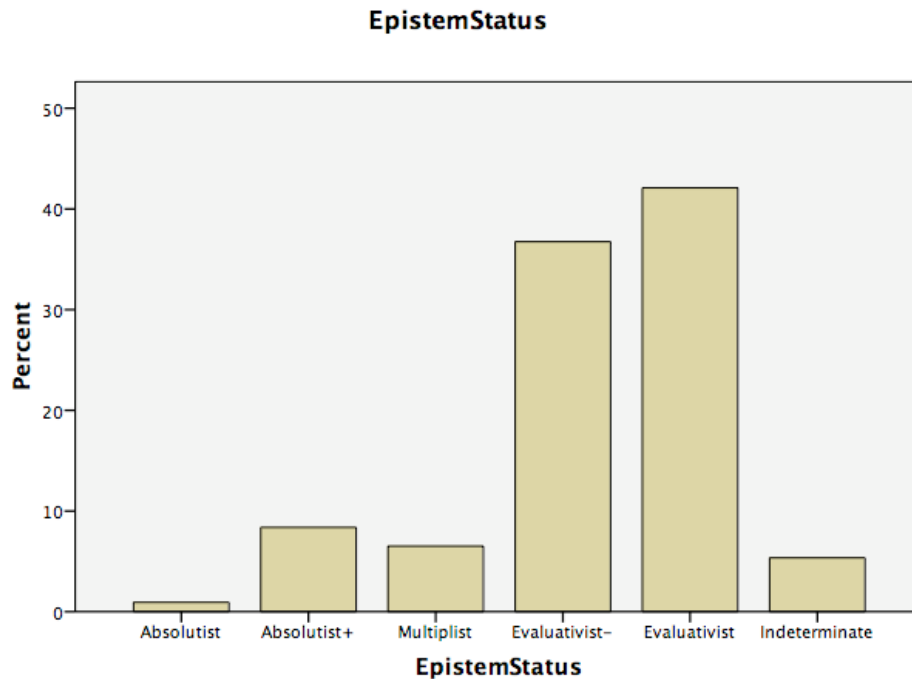


Figure 2. Chart showing Distribution of Personal Epistemologies from the Kuhn Instrument and the Year 9 sample (n=430).

Measures of Epistemological Beliefs about science

Students were asked to respond to a set of statements assessing their formal epistemological beliefs which has 4 subscales. Factor analysis has shown these to be unitary and values for Cronbach alpha exceed .7 for all scales. Scales were scored on a 5-point scale from ‘strongly agree’ (1) to ‘strongly disagree’ (5). In the case of the Source and Certainty scales, disagreement was indicative of more sophisticated knowledge about epistemic beliefs in science. The reverse was true for the Development and Justification scales so these scores were reversed.

Table2. Mean values for Conley Scales and Standard Deviations.

	Year 7		Year 9		Conley Mean
	Mean	SD	Mean	SD	
<i>Source</i>	3.34	.80	3.62	.72	3.68
<i>Certainty</i>	3.45	.77	3.69	.65	3.38
<i>Development</i>	4.15	.44	4.16	.44	3.90
<i>Justification</i>	4.22	.41	4.10	.46	4.26

Conley’s results obtained with US 5th graders using this instrument were higher than the values obtained here for Source, similar for Justification and lower for Certainty and Development. This is somewhat surprising given that our data were obtained from students in Year 7 who were at least one, if not two years older. There was a significant difference ($p < .01$) between year 7 and Year 9 students in the sophistication of their views about Source, Certainty and Justification of scientific knowledge. No such difference existed for the Development scale. However, in all cases the differences are not large. The important feature is that the mean responses for Source and Certainty have improved between Year 7 and Year 9. The same is not true for Development and Justification suggesting that they may have plateaued.

An analysis of the correlation between student responses to the Kuhn items (a measure of their practical epistemologies) and their mean responses for the Conley items using Spearman’s Rank Correlation coefficient gives the following data:

Table 3. Correlations between students’ practical epistemologies and their formal epistemologies ($p < 0.01$).**

	Year 7	Year 9
<i>Source</i>	.163**	.252**
<i>Certainty</i>	.300**	.248**
<i>Development</i>	.063	.138**
<i>Justification</i>	-.034	.011

The main feature to emerge from this analysis is that, whilst significant for both the Source and Certainty scales for Year 7 and Year 9, and significant for the Development scale for the Year 9 group, the correlations in all cases are only small. In the case of the Justification scale the relation is not significant and there is an indication that the two are negatively associated for Year 7. The lack of a stronger correlation is, at first site, somewhat surprising. One possible explanation is that this finding is a consequence of the fact that most students are relatively sophisticated in both their personal (practical) epistemologies and the ideas that they held about the formal epistemology of science which would weaken the strength of the association between the two measures. Another, which we will discuss later, is that these instruments activate different epistemological resources which are relatively unrelated.

Analysis of Student Interviews

Student Interviews were conducted with a total of 108 pairs of students. The data presented here are drawn from a preliminary analysis of the data from 36 pairs from both year 7 and year 9. The interview schedule explored both their knowledge of the formal epistemology of science – in particular, their understanding of the role of facts, theories and evidence in science and their practical epistemology by asking them to consider two instances where there were multiple competing explanatory theories. In the first of these tasks (Task 1) they were asked to decide between two contrary theories for how we see (because light enters the eyes or because vision is active) and, in the second (Task 2), between three differing explanatory theories for why things float and sink – none of which were scientifically correct. The particular focus of this work was on whether they were able to identify whether evidence supported one theory, challenged another or was irrelevant. In particular, whether they recognized the existence of a conflict, and how they then resolved the conflict generated by evidence which challenged the existing theory that they had initially supported.

Understanding of Scientific Epistemology

The interview began with asking whether they felt ideas about climate change to be a fact or to be a theory. 31% of the pairs felt it was a theory and 81% to be a fact (percentages come to more than a 100% as some pairs felt it was potentially both). Predominantly, those who believed it to be a fact referred to the levels of CO₂ in the atmosphere as the evidence that gave it the status of a fact:

Student: Because the way the climate is evidence that it is. Because of CO₂ and they have been measuring the air pollution.

Four fifths of the pairs were able to give examples of both what they felt were theories and facts. The strongest feature to emerge from the interview was that in 97% of the pairs, the idea was advanced that facts were the product of theories that had been proved. This was very much articulated in terms of notions that things could be seen and had been tested:

S1 You can prove it.

S2 Yeah, it is that you, it's been proven that it's changing, you can't say that a football is not a football, you can't...it is a fact, isn't it? It's like...

Theories in contrast were felt to be tentative ideas, opinions or guesses (84%) – something that people believed and were, therefore, open to question:

Int: So what do you mean when you say the word theory? What does that mean for you?

S1: It's an idea.

S2: A thought someone has had. They don't know if it's true. They are just guessing.

Our data show that students overwhelmingly see the status of a fact as representing the ultimate achievement of scientific knowledge. In some senses, there is nothing particularly new about this finding which has been established by previous work (Driver et al., 1996; Lederman, 1992). Nor would we wish to argue that students who make this point are epistemological absolutists. The other data that we have gathered would not support such an interpretation. Rather, it would seem to us that students are most likely using the notion of 'proof' in the sense that the knowledge is beyond question – very much in the scientific sense that this is a piece of reliable knowledge that has been consensually agreed by the scientific community. Such knowledge is something which is propagated by teachers and which they acquire and learn. Facts then are statements about the world, which have been shown to be true and beyond question. As Latour (1986) has pointed out, such knowledge is very much the foundation of

textbooks and very much the bread-and-butter of what most science curricula address. However, the issue of concern for us is that the majority of students ascribe lower epistemic status to the notion of a theory using predominantly the lay conception of a theory as little more than an educated guess. Whilst one third of the cohort did acknowledge that theories were more important and 40% recognized that they were of equal importance, and half saw that they had predictive value, only 13% recognized that they had *explanatory* value.

Evaluating Theories

The two tasks we offered the students examined their ability to coordinate theory and evidence. Task 1 gave students two theories to discuss about how we see and has been extensively used in previous research. The first finding of note in this work was that 97% of student pairs picked the scientific theory as the one that they thought was correct. What was of note in this study was that in both task 1 and task 2, nearly all students were capable of explaining how some of the evidence that they were presented with did or did not support their chosen theory. For instance, in the discussion of whether ‘light travelling in straight lines’ for Task 1:

- Int: So light travels in straight lines. How does that relate to the theory? Does it agree or disagree?
- S2 Disagree. ‘Cause it is not saying that...
- S1 It’s not saying that they don’t travel in straight lines but it is not saying that they do. And I already know that’s true.
- S2 Yeah.
- Int: So do you think it agrees or disagrees or does it not matter?
- S1 It doesn’t agree but it doesn’t disagree.
- S2 I think it agrees with both of what they say but I don’t think it really has that much relation with what they think, because they are talking about how they travel.

Table 4 beneath shows the standard ways in which students were found to respond when presented with conflicting evidence during Task 2.

Table 4. Mode of Response to Conflict (total more than a 100% as some students used more than one way of resolving the conflict).

Mode of Response	Percentage using this response
Accommodates Evidence	21.62%
Changes Theory	24.32%
Qualifies/Accommodates Theory	32.43%
Maintains Theory	27.03%
Reject all-Creates new Theory	8.11%

The conclusion we draw from our analysis is that students’ practical epistemologies, when confronted with the need to co-ordinate theory and evidence show some degree of sophistication. 78% of students recognised the conflict and attempted some form of reconciliation which space does not permit us to illustrate. The failure to change theory or to develop a new theory in the light of cognitive conflict should not be seen as an epistemological weakness. The work of Chinn and Brewer (1993) and Leitão (2000) has shown that it is rare for this to be the immediate response to conceptual conflict.

Conclusions and Implications

Any conclusions to be drawn from this data set are tentative given its limited nature. We recognize that there are considerable weaknesses in attempting to identify either students' epistemological beliefs or their practical epistemologies from a short survey instrument and even the short qualitative interviews we have attempted to conduct (Lederman et al., 2002). Nevertheless, what this study does offer uniquely is three data sets that give different windows into students' reasoning and their epistemic beliefs about science.

The data we have obtained from the instruments of Kuhn and from the interviews would suggest that students' practical epistemologies could be characterised as evaluativist or at least inclining towards such practices. Such an outcome is congruent with the findings of Smith et al. (2000) which found that students taught using a constructivist perspective developed an epistemological stance toward science that focused on 'the central role of ideas in the knowledge acquisition process and on the kinds of mental, social, and experimental work involved in understanding, developing, testing, and revising these ideas'. Whilst our data consists of only two sets it is at least indicative of some underlying coherence to their practical epistemologies. In one sense this data does not support Hammer and Elby's (2002) view that personal epistemologies as a loose collection of resources which are invoked by different contexts – in essence a collection of epistemological primitives which are comparatively unrelated. However, the items posed to these students were specifically asking them to take a stance towards certain specific knowledge claims. These would be most likely to trigger Hammer & Elby's epistemological primitive of 'doubting' or 'accepting' and hence, the coherence in these two contexts which do not call upon the other primitives.

In contrast, when it comes to students' understanding of formal epistemologies, there does appear to be a contradiction. The survey would suggest that students' hold comparatively sophisticated views whilst the interview would suggest that they hold less developed views of scientific epistemology where the primary goal of science is seen as the creation of certain and unequivocal knowledge. In one sense, students' responses to the survey could be said to be drawing on Hammer and Elby's notion of 'knowledge as fabricated stuff' where knowledge is seen as something that is constructed and hence tentative and associated with a element of uncertainty which would explain why they appear to be relatively sophisticated. In contrast, the questions in the interview, coupled with their experience of school science, activate the epistemological primitive of 'knowledge as propagated stuff' – an understanding that sees knowledge as preformed and only valid if it has been shown to be 'true' and has acquired the status of a law or a 'fact' (Lederman, Abd-el-Khalick, Bell, & Schwartz, 2002). Hence the tendency to ascribe a higher epistemic status to 'facts'.

This leads us to the view that the way in which knowledge is framed within school science draws too much on the notion of 'knowledge as propagated stuff'. Rather, there needs to be more focus on the notion of 'knowledge as fabricated stuff'. This does not simply mean engaging in more experimentation. In our findings, 48% of students' commented spontaneously on sources of knowledge in science and their responses were dominated by the notion that experiments are critical tests of scientific ideas – essentially the epistemic criterion that must be satisfied to establish something as a 'fact'. Rather, we would wish to suggest, along with Ford, that activating the epistemological resource of 'knowledge as fabricated stuff' requires students to have the opportunity to engage in critical evaluation of ideas and data. It is only this practice which will enable students to see that science is not simply a monolithic body of pre-formed knowledge but that rather scientific ideas are developed by a process of transformative criticism. Indeed that the fabrication of new ways of conceiving of the world is a more fundamental, and more important aspect of science than propagation.

Such an approach would also have value for student learning as a clear relationship between epistemic beliefs and conceptual change has been shown to exist (Andre & Windschitl, 2003; Qian & Alverman, 2000). Students who view knowledge as flexible, changing and fabricated are ultimately more likely to change their conceptions about scientific phenomena. Moreover, students who see knowledge as something which has to be socially and personally constructed are more likely to accept scientific explanations of phenomena (Sinatra et al., 2003). Hopefully, this paper has contributed better to understanding the interrelationship that might exist between students' formal understanding of scientific epistemology and their own practical epistemologies. What it demonstrates is that there is some inter-relationship between the two and, just as it is impossible to imagine constructing a house without a roof, likewise, it is impossible to imagine helping students to understand the importance of theories, evidence and their inter-relationship unless students are provided with more opportunity to see how ideas in science are both constructed *and evaluated*.

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DISCIPLINE-CULTURE FRAMEWORK OF IMPLEMENTING THE HISTORY AND PHILOSOPHY OF SCIENCE INTO SCIENCE TEACHING

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Abstract

Using the history and philosophy of science (HPS) in science teaching can be framed within the paradigm of discipline-culture, which structures fundamental science discipline in three areas – nucleus (the central principles), body of knowledge (applications of the nucleus) and periphery (knowledge elements contradicting the nucleus). All three types of knowledge elements create in the learner cultural knowledge of the discipline and may cause its meaningful learning by (a) cognitive resonance in students serving as a remedial tool for misconceptions, and (b) creating the space of learning in which the "correct" knowledge emerges from a discourse between alternatives. Developing historical cases within European project HIPST we found two types of possible cases: those representing the "correct" knowledge (type I) and those reviving the views alternative to the commonly adopted (type II). We argue for the essential importance of the second type for the meaningful learning of the contemporary taught knowledge in physics classes. By shedding light on the scientific concepts and their operational definition, understanding the meaning of models, laws, theories, experiments the units should cause epistemological maturity, and benefit to the views on the nature of scientific knowledge. Revealing conceptual dialogue between alternative ideas in science not only impedes misconceptions, but performs enculturation of students into science.

Introduction

Using the history and philosophy of science (HPS) in science teaching has a long history and many researchers argued for its benefits to students and teachers (Matthews, 1994). Importantly, the argumentation for using the HPS did not remain as it was but develop with time reflecting cultural evolution taking place (Galili, 2008). However, even after intensive support for using the HPS in science teaching and articulation its advantages in a list of benefits caused by such using (e.g. Matthews, 1994, p. 38), the issue continues to be controversial, as it emerges from research reports (e.g. Galili & Hazan, 2001a). Physics teachers and physics researchers who lecture physics often refuse to significantly include the HPS materials beyond cultural references and anecdotes that remove the tension of formal instruction. There is a widespread myth among science teachers that science teaching can be neutral, free of any philosophy (Tseitlin & Galili, 2006). Historians often criticize the historical materials for teaching and leaning produced by educators, accusing them in presenting "bad history". The philosophers of science, in their turn, cannot conceal their dissatisfaction with the philosophically superficial – and sometimes simply wrong – ideas on the nature of science, suspecting educators in incompetence in the philosophy of science (Matthews, 2009). However, even after all substantial critique, there remain researchers in science education

discourse, who continue to advocate for the enormous potential of the HPS for science education, although they are aware of numerous difficulties of actual application of such materials in class instruction (Gauld, 1991; Galili, 2008, Höttecke 2009). They claim that the current cumbersome situation with the use of the HPS in education has been created due to the complexity of the subject. The situation apparently requires the investment of intensive research effort of both theoretical and empirical nature. Only complementary efforts of both kinds might provide a solid basis and determine the form for the effective use of the HPS in science education. This study belongs to such a trend in science education research. It suggests the framework of the disciplinary knowledge structure in physics, discipline-culture, that not only legitimizes the use of the HPS based materials in physics education, but also argues for its possible *essential* contribution to the meaningful learning of science through addressing the essential features of scientific theories – "critical details" (Viennot, 2004). Moreover, we found it important to distinguish between two types of historical material addressing correct and incorrect scientific knowledge (in view of the modern science) and speculate regarding their relative importance for science curriculum. Finally, the presented ideas were illustrated by describing some features of the historical cases – excursions – that we have recently produced within the international European project for using the History and Philosophy of Science in Teaching (HIPST, 2008).

Theoretical background

Among the reasons for rejection of historical materials by school teachers and university lecturers they mention that such materials are often obsolete and simply incorrect, in light of the present knowledge. Their contents may include conceptions, views, values, terminology that are foreign to the modern learner. Indeed, in education, we do not use the original treatises from the past, but modern textbooks. Thus, even for teaching and learning the fundamental laws of motion in Newtonian mechanics which are obligatory in modern school, we never use Newtonian *Principia*, but we use their modern presentation in a regular textbook (e.g. Halliday & Resnick, 1988), which could be very different in form from the original (e.g. Reif, 1995). Moreover, even when we decide to go and read the original, the *Principia* (Newton, 1687/1999), we immediately discover that the concepts of Newton were different. They look confusing not only to a novice but also to a modern scientist. For example, the First Law of Newton we teach today is not the law formulated by Newton. The original was more complex and in a way different; it was not a special case of absence of force (Galili & Tseitlin, 2003). If so, why do we need the historical materials at all, beyond curiosity and cultural appreciation? Seemingly, many scientists and teachers think so (Galili & Hazan, 2001a).

Prominent physics educators had a difficult time to advocate another view. They claim that the HPS materials are more than historical documents interesting to historians. The focus became to prove the *relevance* of the HPS to the modern learners of science. One perspective of relevance was apparently obvious to many: the HPS materials inform the learner about the features of scientific knowledge and the nature of science as a human activity in which scientists seek the objective truth about the nature and the laws that govern its order and phenomena. This knowledge *about* science – metaphysical knowledge – may enrich the learners through familiarizing with the authentic stories about those who made discoveries and moved forward our civilization (Connant, 1957). The developers of such materials have been motivated for more than sixty years but they never stated anything regarding the inclusion of their materials into the regular teaching in science class. Apologists of teaching strictly disciplinary contents could argue that the HPS based materials are more appropriate for extracurricular activities of those who are interested, not the regular science class. The aspect of the nature of science was not seen as sufficient to justify using the HPS in an ordinary curriculum.

An important change took place with the entrance of constructivism into science education. The latter considers *conceptual change* to be the way in which people learn and hence the goal to be encouraged by teachers. At the same time, the researchers in students' conceptions reported about the high resemblance often found between students' naïve and alternative conceptions and those shown by scientists in the past (e.g. McCloskey, 1983; Halloun & Hestenes, 1985). This similarity revived the thesis of resemblance between philo- and onto-genesis (Piaget & Garcia, 1989). Two these ideas – educational constructivism and genetic epistemology projected to science – created a new perspective on relevancy of the HPS materials. Drawing on the similarity in conceptual difficulties of scientists from the past and students of today researchers of science education stated the worthiness to consider the specific historical ideas in the class (Monk & Osborne, 1997). They stated that those ideas may promote conceptual change or cause a *cognitive resonance* in the learners. Similar motivation was recognized by the program of educational reconstruction which requires *scientific clarification* as well as the knowledge of students' conceptions as a prerequisite in production of teaching materials (Duit et al., 2005). Researchers agreed that appealing to the particular context from the history of science may promote the learner to matching the factors required for conceptual change (Posner et al. 1982): dissatisfaction with the knowledge held together with plausibility, intelligibility and fruitfulness of the scientific alternative.

This approach was tested by us in a year long experiment in which students of the 10th grade (4 classes in different schools) were taught about light and vision in a special course that integrated fragments from the history of optics: from Greek philosophers of nature to the modern scientists. The results were encouraging: at the end of the course the students of experimental program showed better content knowledge in comparison to a regular class as well as more mature views on the nature of science (Galili & Hazan, 2000, 2001b).

New approach: Discipline-Culture

We have suggested a new framework of disciplinary knowledge presentation in educational context, which we called *discipline-culture* approach (Tseitlin & Galili, 2005). Within this framework, there is a clear distinguishing between three types of knowledge elements constituting the fundamental theory in science (Fig. 1). The first type – *nucleus* – includes the paradigm of the considered theory, its concepts and principles, including the rules of theory application. The second type – *body* – includes the application of the central paradigm, solved problems, and explained phenomena, the knowledge of instruments and appliances all built by using the principles of particular nucleus. Together the two areas (nucleus and body) represent what is normally considered as *disciplinary knowledge*. The third type of knowledge elements represents the conceptions that contradict the nucleus, alternative ideas whether from the past or from more advanced theories in future, unexplained phenomena, all other unresolved problems and the information about shortcomings, incompatibilities and failures of the considered nucleus. All these elements comprise *periphery* of the considered theory, and all areas together comprise a discipline-culture. The relation to culture is justified by the fact that the whole body of three types of knowledge include alternative views on the same subject (from the nucleus and periphery) and this feature fits the modern perspective on culture as containing several alternative perspectives on the same subject (in a way, a pluralistic picture).

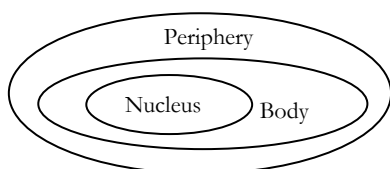


Figure 1. Discipline-Culture structure.

For example, the Classical Mechanics, as a discipline-culture, includes the principles and concepts of Newtonian mechanics in its nucleus, whereas the periphery includes the principles of Aristotelian physics as well as of Einstein's theory of relativity. Misconceptions with respect to the Newtonian mechanics also belong to its periphery in this inclusive conceptual structure. It is clear that the history of science provide a plenty of knowledge elements to the periphery of any discipline presented in a cultural way.

Furthermore, we should realize that a structure with separated nuclei, partially overlaying areas of body knowledge all together immersed in the periphery (Fig. 2) could represent two different fundamental theories and explain the meaning of the *principle of correspondence* between physical theories, for example, between Classical Mechanics and Relativistic Mechanics. Their nuclei contradict each other (for example in regarding space and time) and thus are located each in the periphery of the other. The theories may produce non contradictive results (such as at low velocities) which belong to the overlaying area of the bodies of knowledge.

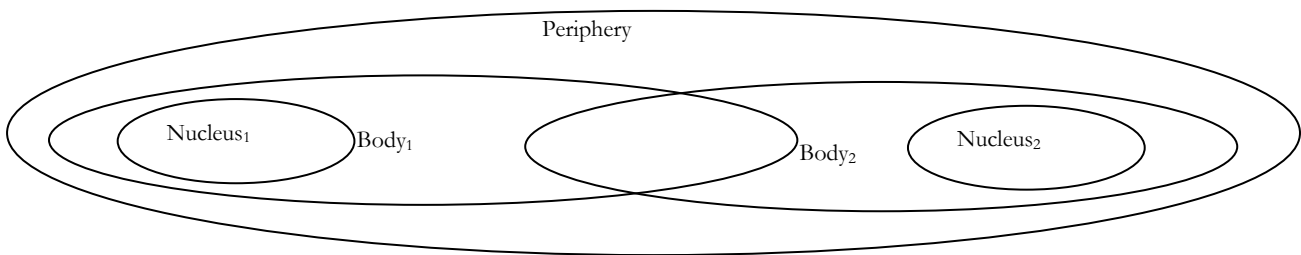


Figure 2. Discipline-culture structure of two fundamental theories.

Being different in the fundamental principles the two theories possess *family resemblance* (Wittgenstein) as is manifested in the shared concepts, methodology, principles, mathematical formalism, etc. We thus have arrived at the structure that represents knowledge of a discipline like physics in cultural perspective.

The role of the Philosophy of Science

Discipline-culture approach led us to further refine the presented arrangement of scientific knowledge with regard to its meaning (Tseitlin & Galili, 2006). We found possible upgrading the semiotic triangle, commonly relating the triad object-concept-sign (Fig. 3a), to the triad of cultural phenomena: Science-the_Philosophy_of_Science- Science_Curriculum (Fig. 3b). Within this perspective, the role of the Philosophy of Science becomes clear as providing the conceptual meaning to the scientific contents and prescribing the features and contents to the science curriculum. Indeed, any philosophical approach – empiricist, rationalist, constructivist, and so on – originates the correspondent curriculum for science teaching which applies its worldview.

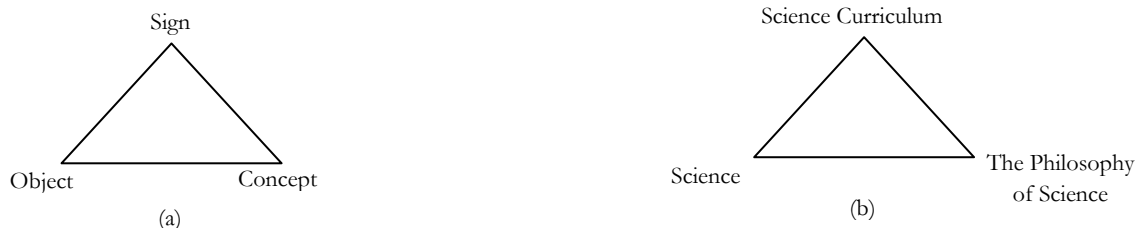


Figure 3. (a) Generic semiotic triangle; (b) The semiotic relationship of Science, the Philosophy of Science and Science Curriculum.

The philosophy of science explains both aspects of conceptual meaning of scientific knowledge: epistemological and ontological, both too often not sufficiently emphasized in textbooks. Importantly, the presented view on the role of philosophy may suggest resource for reliable knowledge required in the discourse on the nature of science, remaining controversial among the education researchers (Matthews, 2009).

Implication to Physics Education: Cultural Content Knowledge

We have learned from the recent history that several projects that tried to introduce the HPS based materials into science education had very modest results:

... even materials produced for teachers, for example, those produced in the UK ... are not used. Attempts to produce restructured courses that put history at the center of the enterprise ... have enjoyed only marginal success, as have those that have sought to introduce a more rigorous and current view of the philosophy of science ... (Monk & Osborne, 1997)

The European project HIPST provided us with a unique opportunity to reconsider the framework of using the HPS materials in light of the previous experience in the subject and the mentioned above research results. In particular, we took into account the described model of discipline-culture to serve as a guiding framework for the new teaching contents.

The feasible format of the new materials aimed to contribute to the existing system of science education appeared to be historical cases which can support the regular course in its particular points (Fig. 4). This is because our intention was to enrich and improve the currently adopted science curriculum and not to replace it.

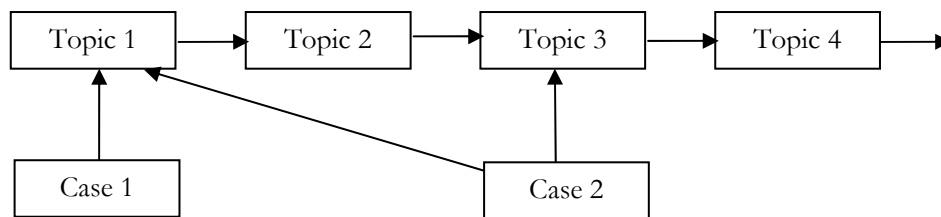


Figure 4. Schematic presentation of incorporation of historical cases into the existing curriculum.

The genre of historical case – or *historical excursion*, as we termed the case when it included a comprehensive account of certain subject expanded along a significant historical period – is by all means special in its features. It has a clear focus in content – theoretical, methodological, instrumental or social. This allows the case to serve as an effective pedagogical tool the particular subject chosen for its importance. The cases must be compact by their nature, and as such they can be manipulated by the teacher and adsorbed by the instruction. They may include a story, a sort of narrative, known as an appealing format for class teaching which yields better mastering the chosen topic. The problem raised was to establish the criteria, guiding principles in choosing the materials for such cases.

For this purpose one may use the culture-discipline structure as a reference framework. Having in mind the elements of the curriculum affiliated to different areas of the discipline-culture structure, we could imagine two basic options existing in developing our historical cases (not excluding their combination) (Fig. 5).

I. In the first case, the contents address the nucleus or enrich the body knowledge of the theory. For example, such historical cases could address the story of lever, Archimedes' law of buoyancy, Eratosthenes' measurement of Earth radius, discoveries of microscope and telescope, Cavendish's "weighing the Earth"; the story of Ohm's law and many others. The common in all these cases is that they present the knowledge proved to be correct by the following history of physics. We label such cases as Type I historical cases.

II. In contrast, the historical case of Type II addresses the contents, which were shown to be wrong by the following history of physics. Of course, their selection is not arbitrary. One deliberately chooses the content, which contrasts the central paradigms of the currently adopted theory, the subject of learning. Aristotle's mechanics, Pythagoras' theory of vision, Impetus theory of medieval physics, and Caloric theory of heat can all exemplify such contents. Each of the mentioned constructs presents an alternative to the nucleus and challenges certain fundamental theory included in the current physics curriculum. As such, the case of this type deals with the periphery knowledge of the theory and touches on the contents of the nucleus.

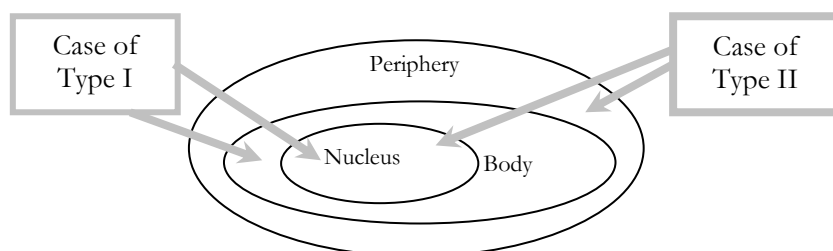


Figure 5. Two types of historical cases and the areas of their affiliation.

On the first glance, it might appear that using the cases of the first type is natural and of those of the second type – problematic. A more deliberate inspection, however, may change this impression.

Indeed, although the contents of the cases of type I could be interesting and enriching the knowledge of the learners, conceptually their contribution is not unique to study the discipline. Therefore, these materials could be, in principle, replaced with other materials that cover the same subject matter without historical reference. Of course, such teaching would lose the special attractiveness of historical narrative, demonstration of the social aspects of scientific knowledge and the illustrative power of displaying the features of scientific enterprise in the authentic environment. The cultural literacy of the learners would also suffer from such strategy. However, teaching without this type of materials is possible, and in fact it is common on our days, being justified by lacking of time and the need of disciplinary focus in physics class. For example, one may teach about the lever, as well as all other simple machines, without any reference to the rich history of their use. Instead one may use examples from the everyday life, familiar to the student. Therefore, one may say that using Type I cases is not essential for physics teaching.

Considering the cases of the second type is more complex. Some science educators furiously deny the use of such materials claiming their misleading and confusing influence on the students whose perception of ideas is not sufficiently mature and their knowledge is vulnerable. Indeed, these materials "revive" the obsolete ideas in science, refuted, often with great efforts, and replaced with other theories, sometimes also refuted later in the course of history. Why confuse the novice learners? Why mount on their way "artificial obstacles", which once were barriers to the progress of science? There is a good answer to this worry, and in fact, more than one. Here are they:

1. Controversy of the scientific knowledge, which is demonstrated by the elements of periphery, presents one of the major features of the conceptual ecology in which the scientific knowledge emerges. It is the existence of controversy that clearly distinguishes the scientific knowledge from other types of knowledge which learning is often based on indoctrination. Introducing elements of historical debate into the process of teaching, converts learning into inquiry, creates in the learner an adequate image of science and the scientific enterprise. Multiple ideas regarding certain subject testify for the competition between the different conceptions prior to adoption of the current way of understanding. This feature provides scientific knowledge with a special reliability and maturity.

2. It is a conceptual debate that makes science especially attractive to many learners of science. Certain part of young people are motivated to learn science just because they see in it a living body of human knowledge engaged in self correction, basing on reasoning, a fair play of ideas, a "play" in which they can participate not as passive observers and absorbers, but as those who may join the endeavor of inquiry as participators who may take a side, argue on their own. For this type of learners the periphery knowledge is of more interest than other contents of science curriculum. Keeping with strict disciplinary presentation we often lose this type of students.

3. As was mentioned by many not once (e.g. Monk & Osborne, 1997; Galili & Hazan, 2000), the similarity between the obsolete conceptions in science and naïve conceptions of students may be used in a remedial strategy of discussing certain idea from the past in order to refute it and thus cause the required conceptual change, or at least, a cognitive resonance in the learner. Candidates for such remedial discussions are recruited from the periphery knowledge. In the following we will illustrate this idea by specific examples of the units we have developed.

4. In fact, certain elements of obsolete scientific knowledge essentially surpass a mere remedy role. Those are the old conceptions which are alternative to the nucleus of the contemporary theory. Such are, for example, the conceptions of motion by Aristotle and Buridan. The claim is that these conceptions from the periphery may establish a reasonable conceptual variation to the considered element to be learned and by this create a space of learning, necessary for humans (Marton et al., 2004). The process of learning is fundamentally different from loading new information; it presumes a space of ideas in which human cognition construct knowledge through permanent comparison between plausible possibilities. This way people provide their new knowledge with meaning, make sense of it. This happens whether or not the teacher provides the candidates for this process from history. Explicit inclusion of periphery in teaching facilitates this process in the most relevant direction.

The demonstrated importance of the periphery knowledge has brought us to the major implication of the discipline-structure framework to science education: the requirement of Cultural Content Knowledge (CCK).

Cultural Content Knowledge is the disciplinary knowledge upgraded by its periphery.

CCK is related not only to education. It is valuable for science researchers, historians and philosophers of science. However, in those areas CCK is not new and was always respected as an important feature of knowledge. It is developed by training and/or through continuous, years long practice, personal instruction of a master and individual learning. It is, however, with regard to the science education that CCK is often neglected and underestimated. The evidence for that is the fact that teacher training programs, at least in our country, do not include any materials from the HPS. Our study suggests the necessary change of this erroneous practice.

One can relate the CCK to another paradigmatic concept of science education – the Pedagogical Content Knowledge (PCK – Shulman, 1986). One can show that CCK significantly upgrades PCK (Fig. 6), providing it with new hitherto not used possibilities significant for education.

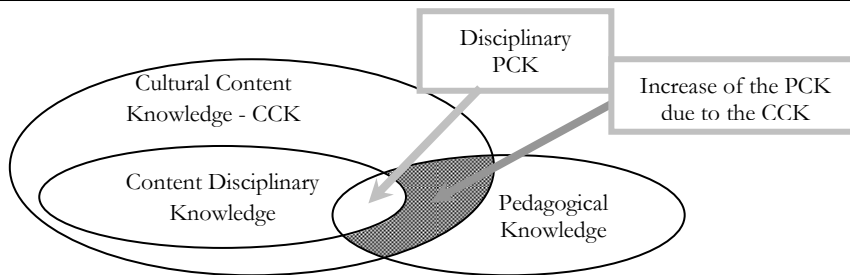


Figure 6. Symbolic presentation of the impact of CCK on the PCK.

We have described our vision solely with regard to the disciplinary contents of the historical cases. By all means, there are other aspects important within the holistic scope of educational validity, to name a few: social, instrumental, moral, and feministic dimensions.

In the following, we illustrate the presented above rationale by addressing several from the historical cases we have comprised within the HIPST project.

Case 1. Understanding Classical Mechanics: A Dialogue with Cartesian Theory of Motion

In this historical case, we perform an excursion to mechanics just prior Newtonian theory. We address the laws of motion suggested by Descartes in his *Principles of Philosophy* (1644) thoroughly studied by a young student of Cambridge, whose name was Newton, and who later, years ago, disputed with the great philosopher and provided different answers in his *Mathematical Principles of Natural Philosophy* (1687) that became a cornerstone of the Classical Mechanics. The excursion presented Descartes laws and their implications – the rules that govern collisions between hard objects. We elaborated the central revolutionary ideas of Descartes regarding motion: motion as a state instead of process (in contrast to all previous physics), the law of inertia, conservation of quantity of motion, the account of collisions. All these were adopted and further developed by Newton. At the same time, we focused on the mistakes made by Descartes, which are relevant to the modern curriculum of mechanics at high school: quantity of motion as a scalar (instead of vector), distinguishing between motion and rest (instead of their equivalence in accord with the Principle of Relativity of Galileo), the argument by God's nature (unacceptable today), wrong rules of collisions (violating relativity of motion). Besides the detailed critique, we provided the following history of refutation Descartes rules of collision, first empirically, by John Wallis and Christopher Wren, and after then, theoretically, by Christian Huygens, through his ingenious application of Galileo's principle of relativity. We showed the pioneer work of Huygens who involved two observers to account for physical situation and succeeded to deduce the conservation of kinetic energy (*vis viva*) in elastic collisions, both much before these results became a part of a solid formalism in physics.

Not less important inferences were available in this excursion with regard to the nature of scientific method. The students will have a chance to follow the great mind of Descartes who applied the method of rational metaphysical reasoning to physics. Importantly, his results were refuted first by the empirical method of experiments with controlled variables, and then, by providing theoretical account of collisions by Huygens. Eventually, an authentic picture of the scientific method – as a continuous cycle of theoretical (deductive)-empirical (inductive) treatment, without isolated start and finish – was attained and became available for discussion in physics class. Albeit refuted, many claims of Descartes remain important to reproduce the authentic debate in science. Students receive a chance to share the great debate in the foundation of classical mechanics and grasp the principles belonging to the nucleus of this fundamental theory. The meaningful learning may be reached here due to the historical case of Type II.

Case 2. The Pre-Newtonian Theory of Motion: the Theory of Impetus

The theory of Impetus was a great success of the medieval science in the continuing progress of physical science from the time of Aristotle. It was in the debate with impetus that the concepts of modern mechanics evolved by Galileo, Descartes and Newton. All too often this theory in particular and the great achievements of mediaeval science, in general, are neglected in modern education. The considered excursion tries to correct this shortcoming. It presents and discusses the development of the central paradigm of mechanics – the account of motion (the nucleus of mechanics). Impetus – the "charge of motion" – dismissed the need of external mover, as required for the violent motion by Aristotle, and replaced it with the internal change of the moving body. Natural and violent were treated in similar manner. Impetus was a direct predecessor of the modern concept of momentum. This excursion includes both the triumph of impetus over the Aristotelian paradigm, at the time of Buridan, Oresme and others in the 14th century, as well as its following refutation in favor of motion relativity by Galileo.

The conceptual content of this case should resonate with the very strong misconceptions of force-motion relationship ("motion implies force") numerous reported in the research on students' knowledge of mechanics (e.g. McCloskey, 1983b; Halloun & Hestenes, 1985; Galili & Bar, 1992). In light of these empirical results, one may claim the high relevance of overcoming the concept of impetus for the meaningful learning of classical mechanics. This particular goal may be easily missed if students neglect the competitive concept of impetus in their study.

Case 3. The Story of Optical Image

This excursion illustrates the ontological progress in physics with regard to understanding the concepts of optical image and light ray. It reconstructs the development of physical ideas from several Hellenic theories (Pythagorean active vision, Atomists' eidola theory, Plato's hybrid understanding, Aristotle's theory of tension in medium), to the Hellenistic theory of Euclidean rays of vision, and the medieval theory of Alhazen (11th c), and eventually to the theory of Kepler (17th c), currently taught in physics classes within geometrical optics. In parallel, the history of light ray is described following the evolution of ray from being the central concept in theories of vision and light (in the Hellenistic and Medieval physics) to an auxiliary concept in the wave theory of physical optics.

Addressing these contents proved to be potent for remedy of a big cluster of students' misconceptions revealed by investigating students' knowledge resulting the common way of optics instruction. The latter often neglects deliberate elaboration of the concepts of image and ray. Students' schemes of knowledge regarding light and vision show similarity to the conceptions of scientists in the past. This similarity suggests the use of history for remedial influence on students' knowledge (Galili & Hazan 2000). Previously we also observed the positive impact of these historical materials on students' views on the nature of science (Galili & Hazan, 2001b). All together, this excursion illustrates the use of periphery knowledge (historical case of Type II) for improvement of the teaching optics.

Case 4. The Story of Weight and Gravitational force – marriage and divorce

The widespread myth of teaching physics "without philosophy" can be dismissed by the excursion in the history of weight concept. Here, the essential requirement of operational definition by the constructivist epistemology in science (e.g. Margenau, 1950) matches the educational constructivism in tackling with the common confusion of students regarding weight and gravitational force. The history of physics may be elucidative when one follows from the pre-Newtonian understanding of mass-gravity to the classical Newtonian gravitational definition of weight and continues to the split between gravitation and weight, as implied by the principle of equivalence of Einstein (Fig. 7), leading to the operational definition of weight (Galili 2001). Being adopted to teaching, the discussion on this historical development can provide remedy to various alternative schemes (misconceptions) of students in the middle and high schools (e.g. Galili and Kaplan, 1996, Stein et al., 2009), also causing maturation in their views on

the ways to establish reliability of the scientific knowledge. This case addresses the contents of the nucleus of classical mechanics (operational definition of concepts), as well as its periphery.

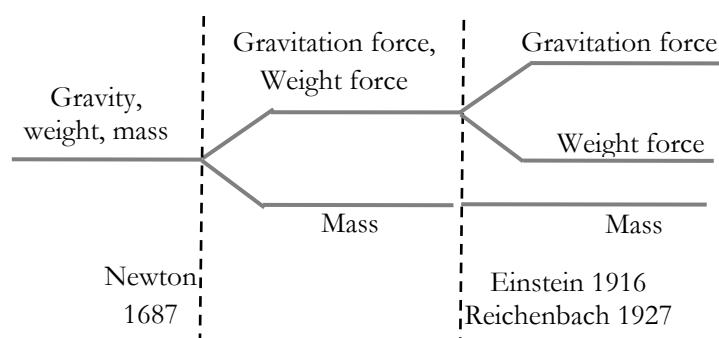


Figure 7. Conceptual evolution of the weight related concepts in physics history.

Conclusions and Implications

We have presented the approach to teaching science which defined Cultural Content Knowledge and argued for its importance for meaningful learning of physics and the quality of knowledge. We have elaborated why and how the history and philosophy of science may play essential role in the educational process seeking genuine understanding of the scientific contents, their hierarchical structure and scientific epistemology. This approach may guide the production of new teaching materials for a culturally rich curriculum. We tried to illustrate the need of deliberate selection of historical materials which does not exclude the use of currently refuted scientific ideas (Type II history) while emphasizing the conceptual debate regarding the conceptions to be developed by students. The discipline-culture approach may reduce the problem of time pressure in class instruction by changing the narrative of presentation the central conceptions and introducing conceptual hierarchy in the curriculum. The HPS based learning material by their nature may significantly improve students' image of scientific knowledge and their views on the scientific method (epistemology). The expected impact of the historical cases developed in the HIPS'T project, to be checked by research, will be the change of the structure of students' knowledge from the knowledge in pieces (diSessa 1993), or scheme-facets clusters (Galili & Hazan, 2000), to the structure corresponding to the cultural knowledge of science.

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AN ASSESSMENT INTO PRE-SERVICE BIOLOGY TEACHERS' APPROACHES TO THE THEORY OF EVOLUTION AND THE NATURE OF SCIENCE

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Abstract

The theory of evolution is the unifying and highly respected paradigm of biological sciences. Despite its important position in biology, research shows that it does not receive expected respect from the wider society. It has been argued that individuals' understandings of science and its nature may have an important role in this. Considering biology teachers' vital role in learning and understanding the theory of evolution by learners, this research aim to assess prospective biology teachers' understandings of the nature of science and their perceptions of the theory of evolution in order to evaluate the potential relationship between the two knowledge domains. The investigation was undertaken in spring 2008 semester, at a major teacher education institution in Istanbul. Total of 75 pre-service teachers participated in the study. Participants' perceptions of the NOS and the theory of evolution were assessed by a questionnaire and semi-structured, face-to-face interviews. The results showed that a significant number of the prospective biology teachers participating in the study had negative attitudes towards the theory of evolution. Detailed analyses revealed one-to-one connections that support the existence of a conceptual level relationship between perceptions about the theory of evolution and understanding the nature of science.

Introduction

The theory of evolution is the unifying and highly respected paradigm of biological sciences and provides a functional framework for biology teaching in school science (NRC, 1998). However, it is clear that the theory is far from its desired status in the public sphere, especially in some countries including Turkey. A recent research published in the 'Science' magazine, for example, showed that Turkey and the USA are the two countries where the theory of evolution is least accepted (Miller et al., 2006). Science education research into the reasons of this objection has revealed that one or more of the following arguments are utilized by students in their objections to the theory of evolution; these include a) conceptual difficulties b) extra scientific explanations (e.g. Aristotelian ideas), c) faulty understanding of the nature of science (NOS), and d) religious beliefs (Dagher & Boujaoude, 1997). Students' conceptual difficulties and appeal to outdated explanations are generally accompanied by a limited understanding of the NOS. It is argued that this limited understanding of many aspects of science, including difficulties in understanding the nature of scientific theories and laws, the demarcation criteria between science and non-science and the importance of indirect evidence in science affect both the attitudes towards and understanding of the theory of evolution (Dagher & Boujaoude, 1997). Improving students' conceptions of the NOS then becomes a necessary, though not sufficient, vehicle for helping them to understand the epistemological foundations of evolutionary theory (Dagher & Boujaoude, 2004).

Without a doubt, biology teachers have the primary responsibility in educating future generations that have a thorough understanding of the theory of evolution. This necessarily requires well equipped and informed teachers with regard to the theory of evolution. Therefore, assessing teachers' views about the theory of evolution and the factors affecting their approaches are of paramount importance. This assessment is especially critical in initial teacher education level, where pre-service teachers develop necessary knowledge and understanding that will guide them throughout their professional lives.

To this end, the purpose of this study is to explore how a group of pre-service biology teachers view the nature of evolutionary theory. By focusing on this, we also address the role the understanding of the NOS plays in shaping their views. Such an assessment will inform us about the effectiveness of a typical teacher education program in developing pre-service teachers' views about the theory of evolution and how, if it does, understandings about the NOS affect perceptions about the theory of evolution.

Methods

This investigation was undertaken in spring 2008 semester, at a major teacher education institution in Istanbul. Total of 75 pre-service teachers participated in the study. Participants' perceptions of the NOS and the theory of evolution were assessed by a questionnaire and semi-structured, face-to-face interviews. The participants' perceptions with regard to these domains were analyzed separately first, then the relationship between the two analyzed in later stages of the study.

The 'Questionnaire to examine acceptance and understanding of evolution and scientific method' developed by Johnsons (1985) was used to reveal the group's overall approach to evolutionary theory. The questionnaire was designed to assess the participants' views about the reliability and validity of evolutionary theory, the nature of evidence about evolution and, the variety of life. Participants' responses to the items are recorded on a five-point Likert-type frequency response scale and the responses to the items were analyzed through descriptive statistics.

The participants' understanding of the NOS was assessed through interviews. Towards this end, in light of the analysis of the responses to the questionnaire, 10 participants having positive or negative attitudes towards the theory of evolution (five with negative attitude and five with positive attitude) were invited for interviews. Semi-structured interviews with these 10 selected participants were conducted in order to assess their understandings of the NOS in detail. In these interviews, the participants' views about various aspects of science, such as the tentative nature of scientific knowledge, the nature of scientific theories and laws and, scientific method, were assessed with special reference to the theory of evolution

Results

Participants views about the theory of evolution

The overall analysis of the participants' responses to the items in the questionnaire reveal that the mean value was 2.99, indicating that the group presented an "undecided" position with regard to the nature and the status of the theory of evolution. However, the detailed analysis of the items in questionnaire showed that significant part of the participants presented negative attitudes towards evolutionary theory and its scientific status. Some of the findings were as follows. Table 2 presents the distribution of the participants' responses to the questionnaire items. The four dimensions by which the participants' attitudes toward the theory of evolution are presented on the left column of the table. The questionnaire items related to these dimensions are presented in the middle column and the distribution of the participants' responses to these items is on the right column of the table.

Table 1. The distribution of the participants' responses to the questionnaire items.

Dimension	Items	Agree %	Disagree %	Undecided %
The reliability of the theory of evolution (x: 2,84)	Q2 The theory of evolution is based on speculation and not valid scientific observation and testing	44	48	8
	Q7 There is a considerable body of data that supports evolutionary theory.	32	37,6	30,4
	Q14 The available evidence is ambiguous as to whether evolution actually occurs.	52	20	28
Scientific validity of the theory of evolution (x: 2,98)	Q1 Evolution is a valid scientific theory.	44	36	20
	Q4 Much of the scientific community doubts if evolution occurs.	49,4	26,6	24
	Q8 Evolution is not a valid scientific theory.	32	54,8	13,2
	S9 Most scientists accept evolutionary theory to be a scientifically valid theory.	32	45,3	22,7
The nature of evidence (x: 3,26)	Q5 The theory of evolution is incapable of being scientifically tested	38,7	41,3	20
	Q10 Evolutionary theory generates testable predictions with respect to the relationships of living things	56	22,7	21,3
	Q11 Evolutionary theory is supported by factual, historical, and laboratory data.	62,7	25,3	12
Variety of life (x: 2,92)	Q3 Organisms existing today are the result of evolutionary processes that have occurred over millions of years	54,7	32	13,3
	Q6 Modern humans are the product of evolutionary processes that have occurred over millions of years.	29,3	53,4	17,3
	Q12 Humans exist today in the same form in which they always have.	54,4	36,3	9,3
	Q13 The theory of evolution brings meaning to the diverse characters and behaviours observed in living things	52,7	32,5	14,8
Overall Mean (X: 2,99)				

First dimension in this framework was about the reliability of the theory of evolution. As seen in the table, almost half of the participants (48%) were disagree with the statement that the theory of evolution is based on speculation rather than valid scientific observations and experiments (Q2). On the other hand, 44% of the participants thought that the idea of biological evolution has a speculative nature and do not rely on valid scientific evidence collected through scientific observations and experiments. This finding was further supported by the participants' responses to the Q7.

Only 32% of the participants viewed that the theory is supported by a significant body of data. %37.6 of the participants, however, did not agree with this statement and 30.4% presented an undecided view. When we add up these numbers, it can be concluded that 68% of the participants did not think or not convinced about that the theory of evolution is supported by adequate scientific evidence. Another question in this dimension was about the quality of the available evidence with regard to the theory of evolution. Strikingly, only 20% of the participants perceived that the available evidence is clearly support the biological evolution. In contrast, half of the participants found the available evidence unclear and ambiguous and 28% were undecided about the quality and the nature of available evidence supporting the theory.

These findings point out that, in general, the participants of the study, that is biology teachers of the next generation, did not find the theory of evolution as a reliable theory in biological sciences. Perhaps, the fact that the participants of this study did not find the theory of evolution as a scientific theory affected their ideas and approaches about the validity of the theory (x:2.98). Indeed, as a response to the Questions 1 and 8, which were assessed the participants' views on whether the theory of evolution is a valid scientific theory, only around half of the participants (44% and 54.8% respectively) provided positive responses. Although there were around 10% differences between the responses to the similar questions, which might be an indication of the existence of undecided participants within this group, the results point out that around half of the participants did perceive the theory as a valid scientific theory (36% for the Q1 and 32% for the Q8) or were skeptical about its validity (20% for the Q1 and 13.2% for the Q8). An explanation for the participants' with negative or skeptical views about the validity of the theory of evolution may stem from their perceptions of scientific community's reception of the theory. As response to the questions (Q4 and Q9) assessing the participants' perceptions of scientific community's reaction to the theory of evolution, almost half of the participants (49.4) believed that much of the scientific community doubts if evolution occurs and a significant part (45.3%) believed that most scientists did not accept evolutionary theory as a scientifically valid theory. Further, the percentages of the participants who were undecided about these two questions were not insignificant (24% and 22.7% respectively). Another factor contributing to the participants' negative approaches to the validity of the theory of evolution might be related to their perceptions of the methodological approaches utilized in evolutionary studies. The results indicated that the majority of the participants either did not accept the methods of evolutionary biology valid and reliable or undecided about the validity of methodological approaches. Only 32% accepted the knowledge produced in this domain as the result of sound scientific research and methodology.

The participants also presented unclear views about the third dimension, which was the nature of the evidence in evolutionary biology. Somewhat inconsistent with the views declared to the other questions with regard to the validity and reliability of the theory of evolution as a scientific theory, majority of the participants (62.7%) articulated that the theory of evolution is supported by factual, historical and, empirical data. Similarly, 56% of the participants viewed that the predictions generated by evolutionary theory with regard to the relationships of living things are testable. By looking at these results, one may infer that the majority of the participants had an informed understanding of the nature of evidence in evolutionary theory. However, in response to a similar question (Q5), only 38.7% of the participants declared that the theory of evolution is capable of being scientifically tested. An explanation to the controversy between the answers of the participants might be that while the majority of the participants perceived some knowledge in evolutionary biology, such as the relationship of living things, scientifically valid, they were skeptical about some of the explanations that the theory of evolution suggested. Support to this tentative conclusion might be found in the responses of the participants to the questionnaire items in the last dimension.

Indeed, the participants responses to the items in the dimension related to the variety of life indicates that the participants did not grant the same value to all explanations of the theory of evolution. Consistent with the responses provided in the previous dimension, more than half of the participants (54.7%) accepted one of the main claims of the theory of evolution that organisms existing today are the result of evolutionary processes that have occurred over millions of years (Q3). Hence, a significant part of the participants (52.7) agreed that the theory of evolution brings a meaning and explanation to the diversity of characters and behaviors observed in living things (Q13). On the other hand, results pointed out a strong objection (53.4) to the claim that modern humans are also products of evolutionary processes (Q6). 54.4% believed that humans exist today are in the same form in which they always have.

Analysis of the participants' understandings about the NOS

As explained, semi structured interviews were conducted with 10 of the participants (five with negative attitude and five with positive attitude) in order to assess their understandings of the NOS and, at the end, examine any potential relationship between their approaches to the theory of evolution and understanding of the NOS. For this purpose five participants who had positive attitudes toward evolutionary theory (scored over 3.50 in the questionnaire) and five participants who had negative attitudes toward evolutionary theory (scored below 3.50 in the questionnaire) were interviewed. In this section, the participants' views about the NOS are presented first, then, the discussion will proceed to the examination of any potential relationship between their approaches to the theory of evolution and understanding of the NOS.

The interviews yielded rich data about the participants' views about the NOS. The findings concerning the participants' beliefs about the NOS are summarized in Table 3.

This table presents the participants' conceptions about different aspects of science in relation to each other. It also allows making comparisons across the individuals regarding their understandings. In the left-hand column of the table are the themes and statements that have been frequently cited by science education reform documents (e.g., AAAS, 1993) and researchers in various studies (e.g., Abd-El-Khalick et al., 2001; McComas & Olson, 1998; Irez, 2006). These themes and statements are considered as adequate statements that reflect and highlight at least some aspects of science. Using these statements and themes, a holistic summary of the participants' understandings of the NOS was constructed. The participants are placed at the top row. The '■' symbol in each participant's cell corresponding to each theme or statement shows the participant's agreement with the theme or statement in consideration. If there is no symbol then it means that the participant disagreed with that statement. The last column on the right-hand side gives the total number and percentage of the participants agreeing with the theme or statement. By looking at these percentages, one can identify the problematic areas within the group. The last row at the bottom of the table, on the other hand, reveals the total individual scores. The reader can see each individual's rate and percentage of agreement with all the themes and statements presented.

Research literature clearly indicates that students, teachers, lay people and even scientists do not possess adequate conceptions about many aspects of the NOS (Lederman, 1992; McComas, 1998). This research revealed that the majority, if not all, of the participants in this study also held some inadequate and inconsistent conceptions about the NOS.

As seen in the table, there are 13 statements about various aspects of science. Analysis of the interviews revealed that the group's performance was 41/130, which is 32%. It is important to note that total percentages of the participants' agreed with the related themes and statements did not exceed 60% on any of these aspects of science. Overall group percentages with regard to certain aspects of the NOS were extremely low and need careful analysis. The table reveals that only 2 participants indicated that science '*does not rely solely on direct evidence*'. These participants, Turkan and Cigdem, emphasized that scientists make use of indirect evidence in producing explanations about natural phenomena.

"You need evidence for scientific claims; you need to show it to others, if you are unable to show it directly then you need to use indirect evidence. There may be some phenomena that cannot be observed directly, but they might be explained using indirect ways. Consider the explanation about space for example; people were able to understand the spherical shape of the earth using indirect evidence." (Turkan)

Table 3. Overall analysis of the participants' understanding of the NOS

<i>NOS Aspect</i>	Negative attitude toward evolutionary theory					Positive attitude toward evolutionary theory					<i>Total</i>
	Rıdvan	Emrah	Ayse	Pelin	Sema	Turkan	Eylul	Hulya	Seda	Cigdem	
Description of Science											
Science as a way of knowing			■	■		■	■	■			5 (50%)
The empirical NOS											
Does not rely solely on direct evidence						■				■	2 (20%)
Scientific method											
No single scientific method						■		■	■		3 (30%)
Is not a step-wise procedure								■	■		2 (20%)
The tentative NOS											
Scientific knowledge is tentative		■		■		■	■			■	5 (50%)
Theories and laws											
Theories are well sustained		■				■	■	■	■	■	6 (60%)
Theories may change		■		■		■				■	4 (40%)
Due to new evidence	■	■									2 (20%)
New ways of looking at existing evidence		■		■		■	■				4 (40%)
Laws may change	■	■					■				3 (30%)
No hierarchical relationship											0 (0%)
Inference and theoretical entities											
Inferential nature of some theories						■				■	2 (20%)
Creativity and imagination in science											
Involves imagination and creativity				■			■		■		3 (30%)
<i>Total</i>	2 (15%)	6 (46%)	1 (8%)	5 (38%)	0 (0%)	8 (62%)	6 (46%)	4 (31%)	4 (31%)	5 (38%)	41/130 (32%)
	14/65 (26%)					27/65 (42%)					

A similar approach was presented by the other participants, Cigdem. Her example was the nature of evidence supporting the theory of evolution.

“We see (understand) evolution indirectly, there is a lot of indirect evidence and we bring them together... One day enough evidence could be accumulated and the theory of evolution might become a scientific law.” (Cigdem)

No doubt that, one striking statement in Cigdem’s explanation, apart from her explanation about the role of indirect evidence, was about the relationship between scientific theories and laws. Many researchers reported a common misconception amongst pupils, teachers and lay people that scientific theories become laws when proven after repeated testing. This belief was also common amongst the participants of this study. Indeed, the interviews revealed that all participants held a belief that there is a hierarchical relationship between the two.

“Theories become laws when they reach a status that no objection against the theory exist in the scientific community. This is why the theory of evolution is still a theory. Of course it is a scientific theory. But it needs to become a law to be accepted as the truth.” (Pelin)

“... a theory is produced and if it is proven and accepted by everybody, it becomes a law. This is how our knowledge grows.” (Sema)

“Theories are yet to become laws, that is, they are not supported and accepted by all scientists, they are subject to further investigations.” (Turkan)

As seen, some participants holding this view did not only believe that theories become laws depending on the availability of supporting evidence and therefore laws have higher status (Lederman, 1998), but also often fail to appreciate the status of scientific theories, as they believe that only scientific laws represent the “truth” (McComas, 1998). Consistent with the groups’ naïve ideas about the importance and role of indirect evidence in science and the relationship between scientific theories and laws, analysis revealed that majority of the participants did not appreciate the inferential nature of most theories and the place of theoretical entities in science. There were other aspects of science about which the participants presented mostly naïve views. As seen in the table, the majority (7) believed that there exists a universal scientific method. Further, eight the participants claimed that this method is a stepwise procedure. This finding has been commonly reported in many studies of students’ and teachers’ beliefs (e.g. McComas, 1998; Akerson *et al.*, 2000; Abd-El-Khalick *et al.*, 2001). In a similar fashion the majority of the participants expressed inadequate views regarding the tentative NOS. Only five participants acknowledged the tentative nature of scientific knowledge. However, somewhat inconsistent with this finding and showing the inconsistency in participants’ depiction of science, the majority (7) believed that laws do not change. By comparison, the group’s percentages were much higher in some statements about science. Five out of ten viewed science as “a” way of knowing as opposed to “the” way of knowing. Six participants declared that scientific theories are sustained.

Despite this discouraging picture revealed by the groups’ overall performance, analysis revealed that some participants performed better comparing to others. One can see each individual’s score by looking at the bottom of the table. This analysis is important, as it will help us analyze the potential relationship between participants’ attitudes toward the theory of evolution and their understandings of the NOS.

As seen in the table, individual percentages varied from 0% to 62%. The participants who performed significantly better comparing to others were Turkan, Eylul, and Emrah, respectively. The analysis of the interviews conducted with Turkan revealed that she reported consistent views with eight of the 13 (62%) statements provided in the table. Eylul and Emrah presented consistent views with six of the 13 (46) statements. Interestingly, one of the participants, Sema, did not presented any view that were consistent with the contemporary views about science. She continually presented inadequate conceptions about science such as her belief in science’s reliance solely on direct

evidence and their understanding of theory as an unsubstantiated idea. Interviews also revealed some crucial misunderstandings in her conceptions, such as her belief in the hierarchical relationship between scientific theories and laws. It is important to note that her score in the attitude toward the theory of evolution questionnaire was 1, indicating a strong objection to the theory. The table reveals that, in general, the participants with positive attitudes toward the theory of evolution presented relatively more informed ideas with regard to the NOS than those with negative attitudes. Overall score of the participants with positive attitudes was 42% (27/65) whereas overall score of those with negative attitudes was 26% (14/65).

The most significant difference between the participants with positive and negative attitudes toward the theory of evolution appeared to be their approaches to the status of scientific theories. Notably, all participants with positive attitudes toward the theory of evolution argued that scientific theories are well sustained and supported by evidence. Even though many of these participants admitted that they did not feel themselves fully knowledgeable about the theory, they appreciated the status of the theory.

“No doubt that it is a scientific theory... I do not feel that I have enough knowledge about, but it is a reliable scientific theory, and presents us a framework to understand the nature.” (Eylul)

Turkan’s views further support that an informed understanding of the NOS might be a powerful contributor in appreciating the status of the theory of evolution as a scientific theory.

“I see myself insufficient with regard to the theory. I know that I do not possess adequate sufficient knowledge but it is a scientific theory. Because, like all other scientific theories, it is falsifiable. If it is falsified it might be abandoned, but as it is yet to be falsified, it is a valid and well supported scientific theory.”

On the contrary, only one of the participants (Emrah) in the opposite group believed that theories are well supported. This indicates that one of the main reasons for refusing the theory of evolution may be the incorrect belief that theories are not adequately sustained or supported. Emrah’s views about the status of the theory of evolution, on the other hand, once again provide evidence how misunderstanding the nature of theories affects individuals’ approach to the theory of evolution.

“It is true that Darwin’s theory is a scientific theory, but as I said it is a scientific idea that has not been proven... Therefore I cannot say that evolution occurs... there is a significant difference between a theory and law.”

The rest of the participants with negative attitudes toward the theory of evolution claimed that articulation of evolutionary theory as a “theory” clearly proves that the idea is not true.

“It (the theory of evolution) might be a scientific theory, but in order to call it “true” it needs to become a law.” (Pelin)

As discussed earlier, the majority of the participants presented naïve ideas about the nature of evidence in science in that they believed that science uses only direct evidence. However, the fact that both the two participants who discussed that science does not solely depend on direct evidence were members of the group with positive attitudes toward the theory of evolution points out a relationship between understanding the role of indirect evidence in science and the validity of the theory of evolution (see earlier quotes by Turkan and Cıgdem). The accounts of the participants with negative attitudes further supported the relationship.

“It (the theory of evolution) is not scientific. It is not well supported; it neither has validity nor support behind it, because there is no evidence. You need concrete evidence for validity, you need visible evidence.” (Rıdvan)

Another significant finding was about the participants' views of scientific method. Research evidence point out that individuals may approach some claims as non-scientific if they perceive that the claim did not follow the steps of so-called universal scientific method (hypothesis-experiment-theory-law) (Dagher & Boujaoude, 2005). Similarly, some of the participants in this study claimed that the theory of evolution did not complete all of the steps of the scientific method. Sema, for example, appeared to reject the theory of evolution on this basis.

“... there needs to be a hypothesis first, then experiments follow, you prove your claim with experiments and observations. But it(the theory of evolution) is yet to be proven, it is not universal and completed.” (Sema)

On the other hand, the fact that the participants who rejected the existence of such a method were the members of the group with positive attitudes toward the theory provide further support for such relationship.

“... we can talk about scientific method but every individual scientist might have his/her own approach to the problems... that is; investigations in science does not and should not have boundaries.” (Turkan)

“Scientific method is not something that, as traditionally considered, you produce a hypothesis and so on. Each scientists has his/her own way... the questions asked and the method used in producing answers are quite individualistic.” (Hulya)

Conclusions and Implications

This study was designed to assess a group of pre-service biology teachers' understandings about the theory of evolution and the NOS and, thus, to examine the potential relationship between these two domains. The results revealed that the participants generally had negative attitudes toward the nature and status of the theory of evolution than one may expect. The implications are not encouraging: biology teachers who have negative attitudes toward the nature and status of the theory of evolution will inevitably hesitate to teach the theory to their students and will never be able to inspire students in a subject that intrinsically difficult to come to grips with. Thinking the significant role of the theory of evolution in understanding and relating various biological explanations and concepts, it may also be argued that the vast majority of students of such teachers would complete their education with unclear and unexamined conceptions of the theory of evolution and a deep understanding of biology. This would inevitably jeopardise the promotion of scientific and biological literacy in society.

On the other hand, detailed analysis of the selected participants' accounts with regard to the NOS and examination of the association of these accounts' with their views about the theory of evolution implied a potential relationship. This relationship especially obvious when the participants with positive attitudes about the theory of evolution expressed informed views about the nature of scientific theories and the role of direct evidence in science. Clearly, such one-to-one connections support the existence of a conceptual level relationship between the two belief systems and display how specific beliefs regarding the NOS influence individuals' conceptualizations of the theory of evolution. The fact that the participants with positive attitudes toward the theory of evolution expressed relatively more informed ideas about various aspects of science further supported this relationship.

These results point out that more effective education should be given to pre-service biology teachers with regard to the theory of evolution. As an informed understanding of the NOS appeared as a prerequisite for understanding the theory of evolution, any course design intended to teach evolution should pay a special attention to the NOS. Without a doubt, biology teachers with differentiated and integrated understanding of the NOS and the theory of evolution will have greater ability than those whose understanding is limited and inconsistent, to plan and deliver lessons that help students develop deeper and adequate understandings with respect to biology's prime paradigm.

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THE EFFECT OF THE SCIENCE CAMP PROGRAM ON CHILDREN'S VIEWS OF THE TENTATIVE NATURE OF SCIENCE

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Abstract

This study explored effectiveness of nine-day science camp on children's views of tentative nature of scientific knowledge. The science camp was aimed at introducing science to the children. The method of introducing science was guided-inquiry, and several explicit Nature of Science (NOS) activities. The participants were 24 children who were at 6th and 7th grades. To explore effectiveness of science camp on children's views of tentative NOS, VNOS D questionnaire was applied at the beginning and end of the science camp. Three questions in VNOS D questionnaire were analyzed to emerge children's ideas about tentative NOS. The qualitative data were analyzed using interpretive analysis. The results showed that the children's ideas had positively changed toward accepting tentativeness throughout the science camp. More children accepted the tentativeness of scientific knowledge at the end of the camp. They would better explain how scientific knowledge change based on data and any change or addition to the data at the end of the camp. The children's ideas about tentativeness of scientific knowledge in dinosaurs and weather domains were largely affected by the context of the questions although it decreased at the end of the camp.

Introduction

Children's view about tentative NOS is the most searched aspect of NOS. Akerson and Abd-El-Khalick (2005) reported that most of the children at fourth grade held naïve views about tentative NOS. They mostly thought that scientific knowledge changes by technological developments. Only some of them realized that scientific knowledge is based on data and scientific knowledge changes when the data change. Khishfe's (2008) study with seventh graders for 12 weeks showed that the children held naïve views about tentative NOS both before and after the study, and it was difficult to develop their tentative NOS views. Most of the children held a misconception of scientists being certain about their knowledge about the dinosaurs and atoms, because they saw them. Some of the children stated that scientific knowledge would change by the addition of new knowledge. Only some of them holding more informed views about tentative NOS were aware of that scientists inferred their knowledge about dinosaurs and their inferences would change so thus scientific knowledge.

Better results reported by Liu and Lederman (2002) with their study conducted with exceptional children. Most of them accepted the tentativeness of scientific knowledge and would be able to explain that scientific theories would change because of the limitations of a research or when there is new evidence. Khishfe and Abd-El-Khalick (2002) applied a study with sixth graders by implementing explicit NOS activities. They reported that although children held inadequate views about tentative NOS before the study and half of them proposed that scientific knowledge in science textbooks are certain and would not change in the future. Almost all of them stated that scientists are certain about their knowledge about dinosaurs and atom. Their views about tentative NOS developed by explicit NOS activities and half of the children became able to think that scientists could study the events that they did not see and make inferences about them. They also realized that scientists would found new evidence and because of these reasons, scientists would not be certain about their knowledge.

Rationale

The aim of the camp was to introduce science to the children. Guided-inquiry was thought to be the best way to introduce science at a science camp conducted at the nature, because science itself is an inquiry about the nature. Since children would need guidance in an inquiry, guided-inquiry was applied at the science camp. But, science is a complex endeavor which has specific properties that a knowledgeable people about science should know. Such properties are severe, but the basic six aspects of the NOS considered as being convenient to learn for K-12 children. To better introduce science to the children, the camp program was enriched by explicit NOS activities which articulate basic NOS aspects. Explicit NOS activities were proved to be effective in developing children's NOS views (Khishfe and Abd-El-Khalick, 2002; Khishfe, 2008). This paper presents only the findings of the effectiveness of the science camp program on children's views about tentative NOS.

Method

This research was implemented in accordance with a project, 'Three in One: Nature, Science and Children Summer Science Camp, supported by Science and Society Department of Scientific and Technological Research Council of Turkey (STRCT). The purpose of the summer science camp was to introduce science to the children. According to the researchers, science would be introduced by teaching both its process and basic nature. Thus, a camp program was developed by the researchers. The main method of the camp program was a combination of guided-inquiry to learn scientific process and explicit NOS activities to introduce NOS. Science camp was conducted on July, 4-13, 2008 in Bolu, Turkey by a team which included science and mathematics educators. The science camp was carried out at a hotel which was located near a forest. Primarily, a lot of scientific and social activities were done which aimed at developing background for inquiry and collaboration skills in the first three days of the camp. These activities included welcome party, science workshop, mathematics at the nature, black-box activity, and art workshop with waste products. In the following three days, the children worked in small groups and were asked to find a research question about nature which they could answer by conducting an inquiry at the nature. The children worked in the same group throughout their inquiry and guided by a science advisor who were science educators. Throughout their inquiry, children experienced scientific processes such as asking a question, observing, collecting data, interpreting data, concluding and communicating. Then, each group prepared a poster and presented to their families and friends on the last day of the science camp. In most of other sessions in the science camp program, explicit NOS activities were done. The explicit NOS activities implemented in the program were Black Box, Real Fossils, Real Science, Young Woman or Old Woman, The Hole Picture, Tricky Tracks and The Cube (Lederman and Abd-El-Khalick, 1998). In addition to these activities, two activities, Modeling the Bottom of a Puddle and Modeling Earthquake data were developed by the researchers to introduce scientific modeling. The explicit approach was used to introduce NOS throughout these activities. NOS aspects emphasized explicitly and debriefing discussions were conducted at the end of the activities.

Twenty-four children participated to the science camp. Thirteen of them were at 6th grade and eleven of them were at 7th grade. Eleven of them were girls and thirteen of them were boys. Children were selected from ten different elementary schools in Bolu-Turkey according to their interest in science. Science teachers' suggestions were considered in selecting the children. Children participated to the science camp voluntarily.

Views of the Nature of Science Version D (VNOS-D) (Lederman & Khishfe, 2002) was applied at the beginning and end of the science camp in order to determine the effectiveness of the science camp program in introducing NOS. Individual semi-structured interviews were also conducted after questionnaire applications to understand children's views about science better. The interviews were conducted by the researchers. Children were generally asked to explain their answers on the questionnaire in more detail and probed to understand their reasoning. All interviews were audio-taped and transcribed verbatim for analysis. VNOS D consisted of seven open-ended questions about six aspects of the NOS, but only data related to the tentative nature of scientific knowledge is presented in this study. Three questions in VNOS D questionnaire were analyzed to emerge children's ideas about

tentative NOS. Third question in VNOS D was asking if the scientific knowledge in science books would change in the future. Fourth question was about the extinction of the dinosaurs and different explanations provided by scientists. Fifth question was about the weather and building models to predict weather conditions.

The qualitative data were analyzed using interpretative analysis (LeCompte & Preissle, 1993). After transcription of interviews, interview and questionnaire data for each child were combined. Computer software was used to code and organize the data. First researcher coded the data on the software, and other researcher checked the coding and offered changes if she felt necessary. After reaching a consensus on the coding and they decided the categories together. Inductive categorizing and interpreting process was applied. After coding and categorizing, coding schemes were modeled for easy understanding of the organization of the data.

Results

Tentative Nature of Scientific Knowledge in Science Textbooks

Third question in VNOS-D questioned whether scientific knowledge in science textbooks would change in the future (Figure 1). Most of the children accepted that scientific knowledge in science textbooks would change in the future at the beginning of the camp. A few children did not accept tentativeness of scientific knowledge in science textbooks. Children who accepted the tentativeness of scientific knowledge expressed ideas about why scientific knowledge would change such as technological developments, new discoveries, and continuing research.

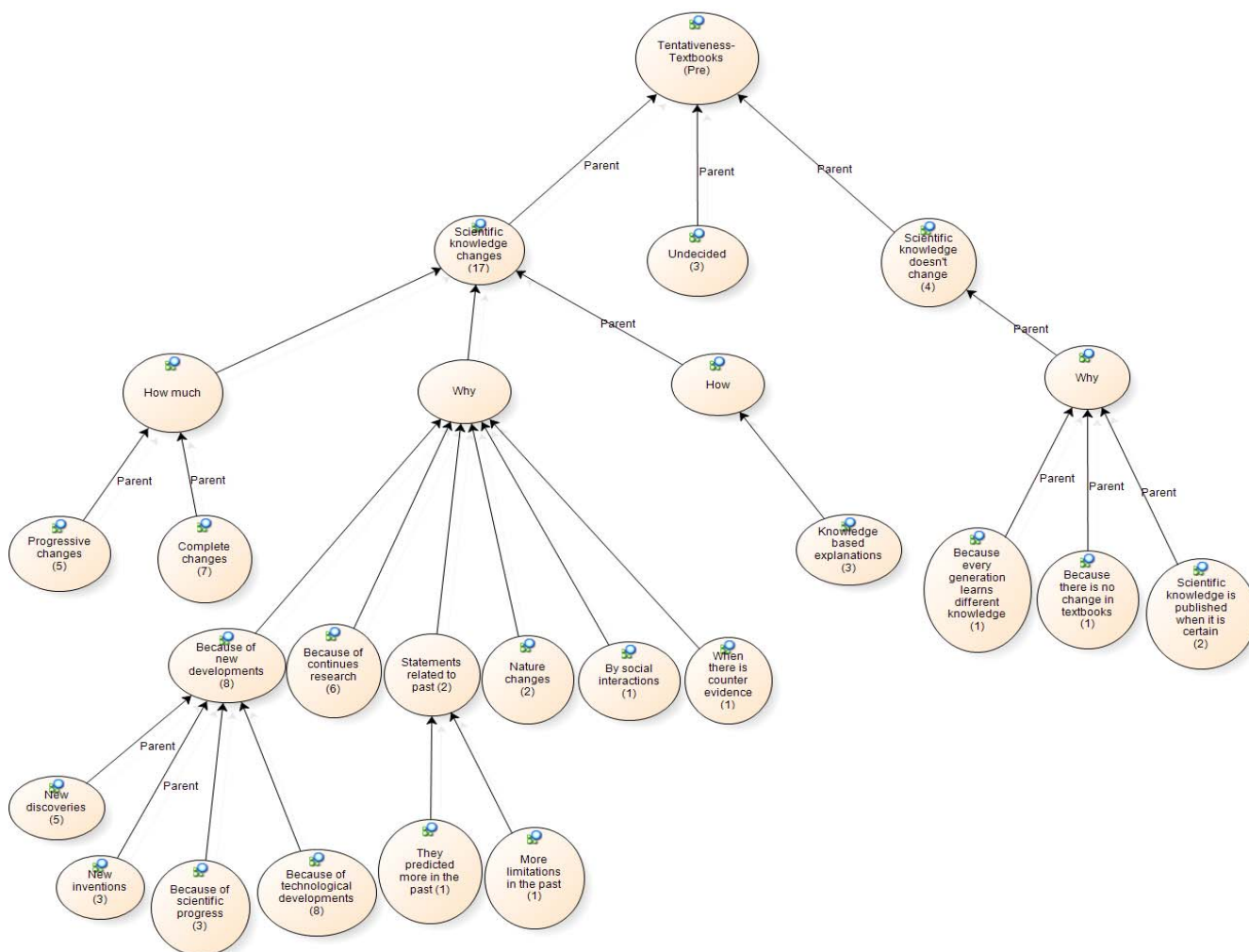


Figure 1. Children's views of tentativeness of scientific knowledge in science textbooks (pre)

Because technology develops in time and previous scientific knowledge will be extended by examining better (Yonca)

Most of the children accepted the tentativeness of scientific knowledge were able to explain why scientific knowledge change, but only a few of them were able to explain how scientific knowledge changes. They explained that scientific knowledge changed as new knowledge was added.

Two of the children who did not accept the tentativeness of scientific knowledge in science textbooks thought that scientific knowledge is proposed when it is certain. One child stated that each generation would learn different scientific knowledge if it changes and other one said that s/he did not see any change in the scientific knowledge in science textbooks.

To me, it cannot change. Because, scientists do not propose scientific knowledge if they are not 100% sure about it. (Murat)

Children also mentioned how much the scientific knowledge would change. Some of them indicated that scientific knowledge progressively changes as new knowledge was added whereas some others indicated that scientific knowledge changes completely. Most of the examples of the complete change in scientific knowledge were about the shape of earth, structure of the atom, and Pluto.

For example, Pluto was a planet in the solar system. But now, it is considered as dwarf planet. Scientists who work on sky discovered bigger planets and thus they put Pluto into dwarf planet category. (Arda)

Some children, indicating progressive change in scientific knowledge, are generally stated the addition of new scientific knowledge to the available scientific knowledge by technological developments.

Yes, it would change. Because, scientists invest a new thing in every minute. As new investigations were made, our knowledge was developed. We developed ourselves and materials. For example, tire was discovered, but did it stay the same? (Berk)

Children's responses to third question at the end of the science camp were modeled in Figure 2. They all accepted the tentativeness of the scientific knowledge. Similar to the beginning of the camp, most of the children thought that scientific knowledge would change through technological developments and continuing research.

It would change in the future. Because it was proposed that the earth was flat. Now, since the technology was developed, they would have gotten more data and they could better determine the real shape of the earth. (Buket)

Positively, more children produced ideas about how much the scientific knowledge would change. Almost all children indicated that scientific knowledge would change completely. Their examples for complete change were again about the shape of earth, model of atoms, and Pluto. Only two children indicated progressive change by stating the addition of new scientific knowledge.

Most positive development in children's ideas was observed about how scientific knowledge would change. Children began to better explain how scientific knowledge changes. Half of the children explained that the scientific knowledge would change if new data were collected. This was the first time the children used data in their explanations.

Because, scientists give scientific knowledge based on available data they have. As time passes on, data and observations will increase and thus, scientific knowledge will also change. (Yonca)

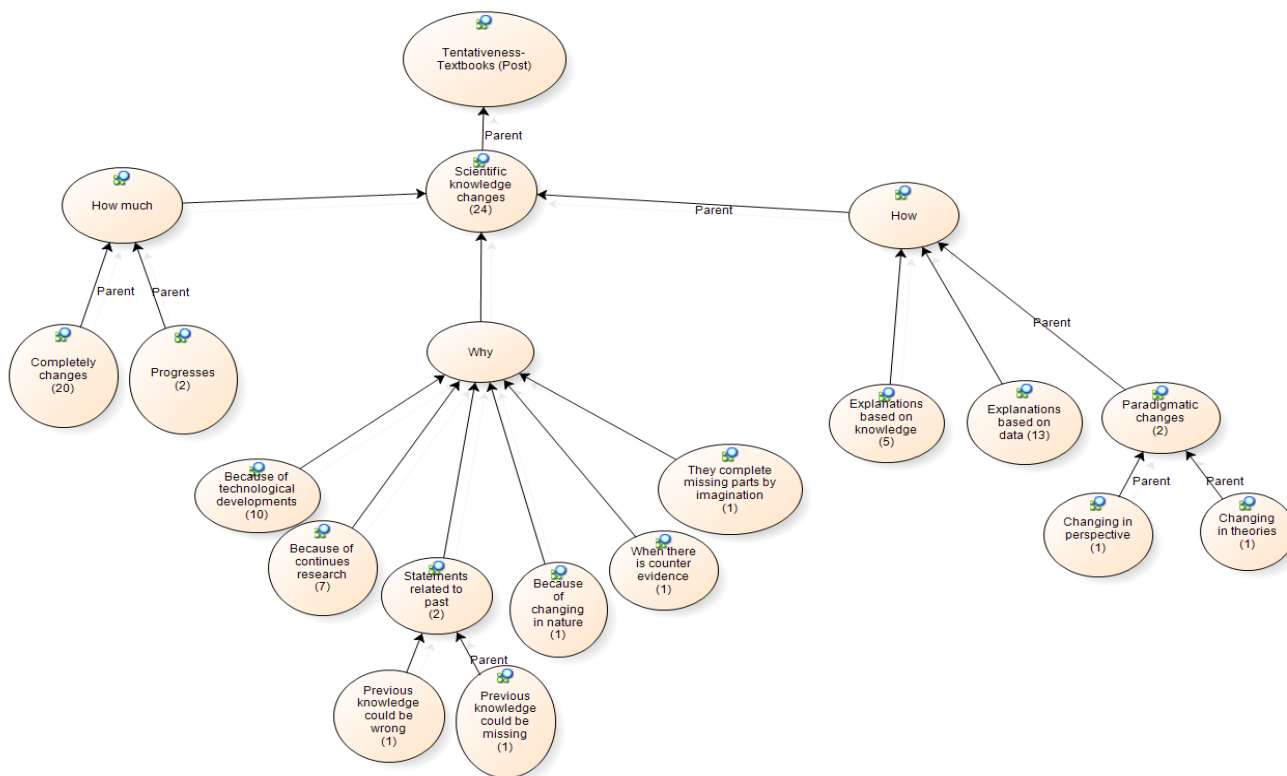


Figure 2. Children’s views of about tentativeness of scientific knowledge in science textbooks (post)

This indicated that most of the children understood the process of scientific knowledge production and they could better articulate the change in scientific knowledge from this perspective. Paradigmatic changes sometimes cause the change in scientific knowledge. Two children indicated this aspect in their explanations.

Because, science would change. Scientific knowledge produced at a time depends on perspectives, experiment, interpretation, imagination, and social environment at that time. As these change in the future, scientific knowledge would change. (Gulden)

Similar to the beginning of the camp, five children did not propose detailed explanations how scientific knowledge would change. They just said that the scientific knowledge would change if new knowledge was added.

Tentative Nature of Scientific Knowledge in Dinosaur Domain

Fourth question asked if scientists are sure about the shape of dinosaurs (Figure 3).

When children were asked if scientists are certain about the way dinosaurs looked, half of the children told that scientist would not be certain about the shape of the dinosaurs at the beginning of the camp. The main reason for this is scientists being unable to see the dinosaurs. Other reasons for scientists being not sure about the shape of dinosaurs were incomplete fossils and lack of evidence. Also some children indicated that scientists use their imagination, thus they can not be certain.

Because, dinosaurs became extinct. There was not any human on earth at that time. Thus, nobody saw them. (Zeynep)

Other half of the children told that scientists would be certain about the shape of the dinosaurs. Some children believe that scientists would know everything about dinosaurs when they found the fossils and they trusted in scientists very much. Since scientists were experienced, they would be certain about their knowledge.

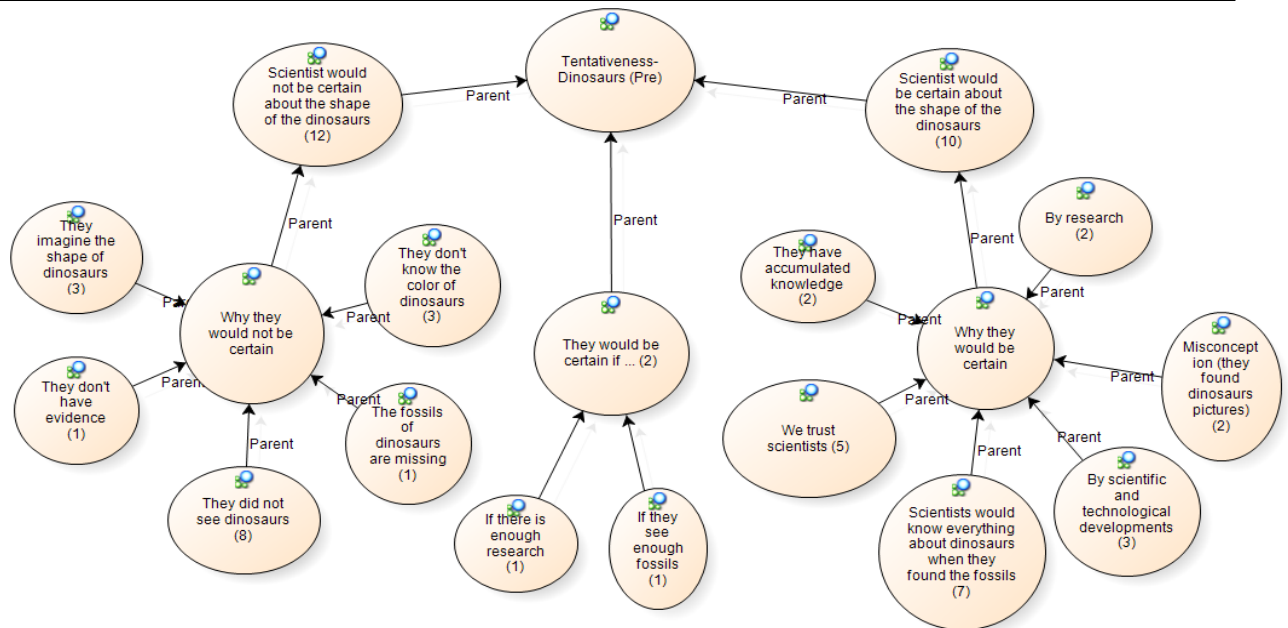


Figure 3. Children’s views about if scientists would be certain about the shape of the dinosaurs (pre)

Scientists know the color and shape of the dinosaurs by examining the fossils. Sometimes only a bone would be enough to determine the shape of a dinosaur. According to me, they are sure about the shape of dinosaurs. Because, they addicted their life to working on dinosaurs. (Giray)

Two children held a misconception about scientists would be certain about the shape of dinosaurs, since they found their pictures on the walls of caves.

Many historical pictures and books reached today. Dinosaurs’ pictures would be in these. For this reason, they are certain about the shape of dinosaurs. (Çağla)

Children’ responses to the question which asked how certain are scientists about the way dinosaurs looked at the end of the camp were modeled in Figure 4.

All of the children became aware of that scientists can not be certain about the shape of dinosaurs. The proposed reasons for this also enriched. At the beginning of the camp, the main reason proposed for the tentativeness of the knowledge about the shape of the dinosaurs was ‘scientists not being able to see the dinosaurs’. This idea still continued at the end of the camp, but it was not the main idea anymore. The main idea at the end of the camp was the use of imagination in deciding the shape of dinosaurs. Most of the children stated that scientists could not be certain about the shape of dinosaurs because they use their imagination and some of them detailed their explanation that scientists use their imagination in determining the shape of the dinosaurs especially when the data is limited or missing.

Because scientists have not got all the data. They make predictions by adding imagination and interpretation to the data they have. They complete the missing data by using their imagination and interpretation. Thus, they cannot be certain. (Funda)

Such children exaggerated the use of imagination in science and some of them like Funda distorted this idea even to scientists completing missing data by their imagination. The use of imagination would be easiest thinking for children to understand how scientists would determine the shape of dinosaurs that they did not see and only found their fossils.

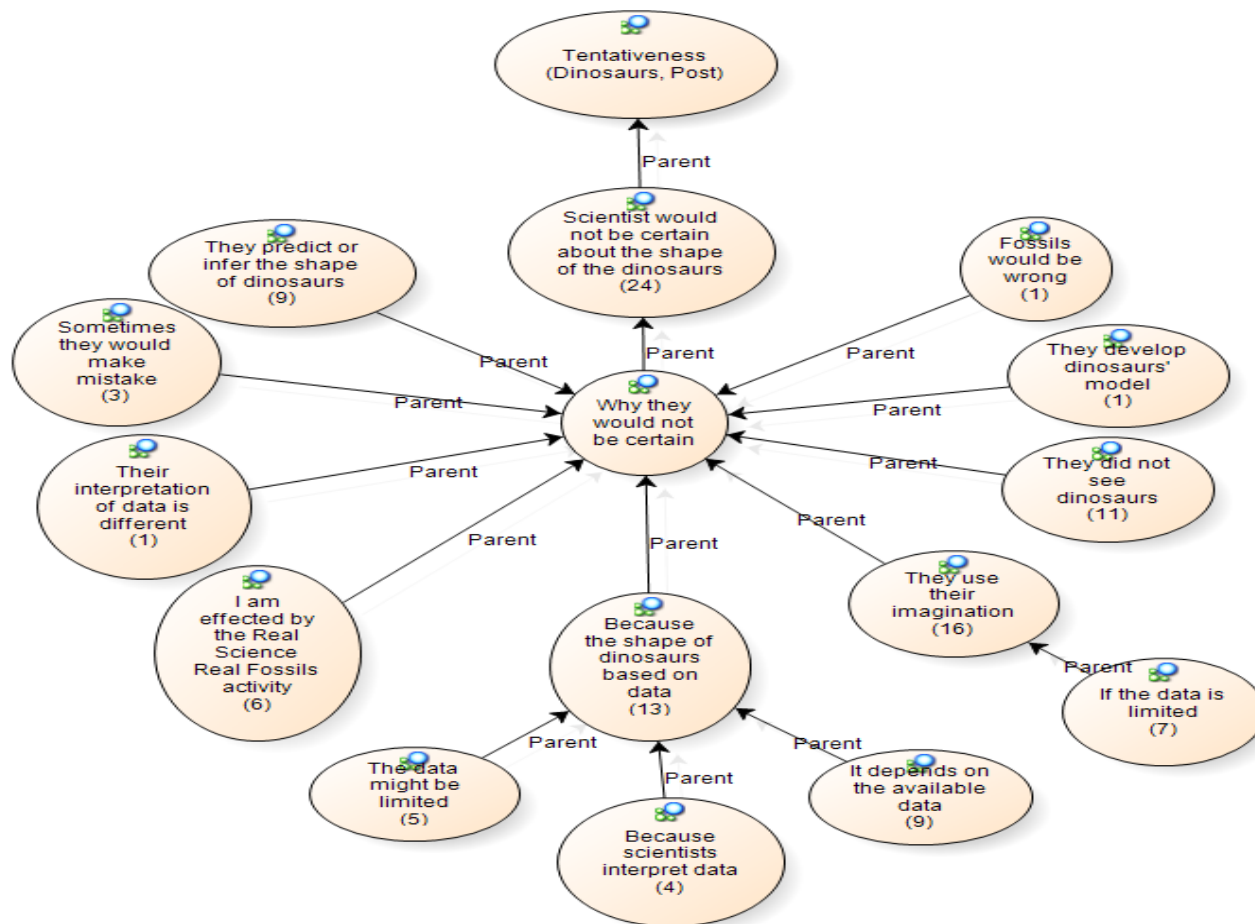


Figure 4. Children's views about if scientists would be certain about the shape of the dinosaurs (post)

Positively, half of the children realized the importance of data in scientists' decisions about the shape of dinosaurs in addition to use of imagination. They began to use data in their explanations. These children thought that scientists would not be certain about the shape of dinosaurs, because scientists would have limited data and scientists interpret data differently. Most of the children indicated that scientist would not be certain about the shape of dinosaurs, because scientific knowledge about the shape of dinosaurs depended on the available data.

Because scientists interpreted the data differently. They would have different view point than other scientists. Since scientists use their imagination and creativity while they are doing interpretation, they cannot be certain about the shape of dinosaurs. Their interpretations based on data, models developed, and even results would change, when new data is added. (Buket)

Some of the children also approached to the idea that scientists infer the shape of dinosaurs by using fossil data. These children did not directly use term 'infer', but they used 'predict' in their explanations. They stated that scientists would not be certain about the shape of dinosaurs, because they found fossils and they predict the shape of dinosaurs from these fossils.

Scientists would know the shape of dinosaurs although they did not see them. Scientists would know the shape of dinosaurs approximately by combining bones that they found from underground. Of course, scientists are not absolutely sure about their shape, because they make predictions like us. (Ahu)

This indicates a positive development in children's thinking about tentative NOS, because some of the children at the beginning of the camp were thinking that scientists would be certain about the shape of the dinosaurs, because they understand everything about dinosaurs when they looked at the fossils.

Children's ideas about the tentativeness of scientific knowledge about the shape of dinosaurs developed through accepting tentativeness of scientific knowledge at the end of the camp. 'Not being able to see the dinosaurs' was main thinking in children's ideas at the beginning. They still kept that idea, but use of imagination was the main thinking in their ideas at the end of the camp. In addition, they were also able to elaborate the tentativeness of scientific knowledge about dinosaurs by indicating that this knowledge based on the available data about the dinosaurs and most of the time the data about dinosaurs are limited and interpretation of the data differently.

Tentative Nature of Scientific Knowledge in Weather Domain

Fifth question which was asking if they think meteorologists are certain about the computer models of weather patterns. Children's responses to fifth question at the beginning of the camp were modeled in Figure 5. Two of three children indicated that meteorologists cannot be certain about the computer models of weather patterns. Children generally stated that weather patterns were predictions, so meteorologists predicted these patterns. Children also said that weather patterns were stated as predictions in weather forecasts and weather predictions sometimes don't come true. This indicated that children misunderstood computer models of weather patterns; they simply thought weather forecasts they were familiar from T.V. Another reason for meteorologists for not being sure about computer models of weather patterns was the dynamic nature of weather. Children thought that weather always changes, thus computer models of weather patterns would not be certain.

When there is a sudden change in the weather, weather forecast does not come true. This shows that they cannot be sure. Indeed, it is weather forecast, they cannot be sure. (Demet)

Being prediction and dynamic nature of weather were two main thinking in children's ideas about the tentativeness of scientific knowledge in meteorology. They did not notice computer model in the question, they mostly concentrated on weather patterns and related weather patterns to weather forecasts in daily life. Thus, being prediction and weather changes in daily life formed their reasoning in thinking about this question.

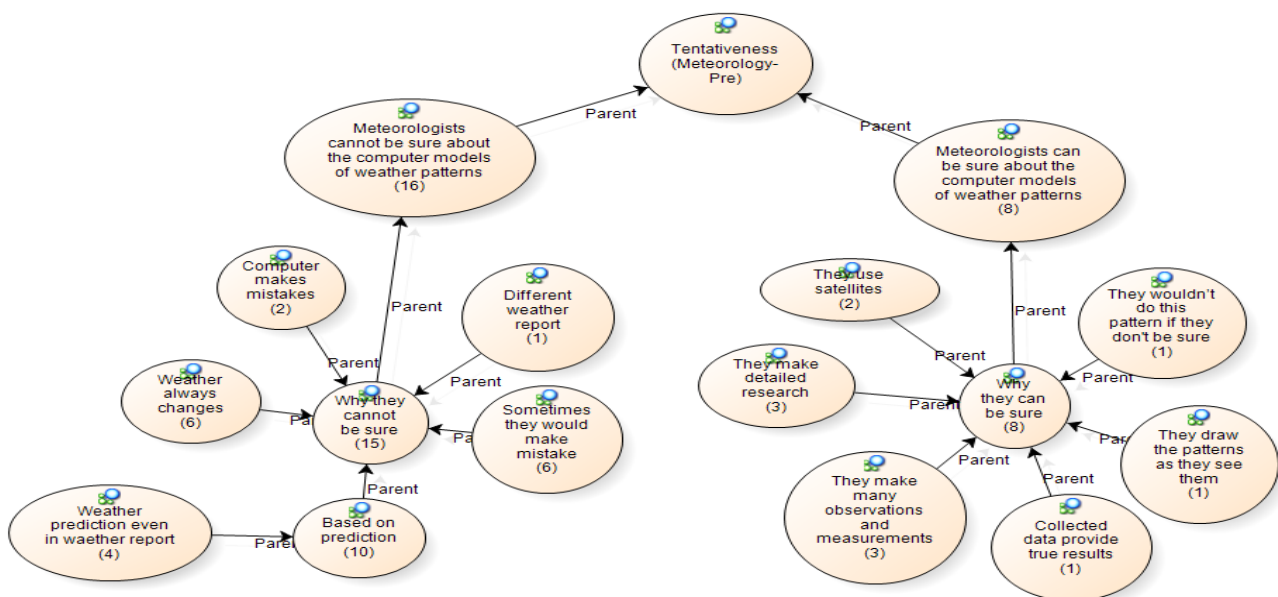


Figure 5. Children's views about if meteorologists would be certain about computer models of weather patterns (pre)

Other children indicated that meteorologists can be sure about the computer models of weather patterns. These children stated that meteorologists use satellite, they make detailed research, they make many observations and measurements, and they draw the patterns as they see them (seeing is knowing).

To me, there is certainty. Because, weather patterns were captured through satellite. Most of the times they (meteorologists) were true. If they say it would rain, it rains. Satellite looking from the sky shows the weather patterns clearly. (Fuat)

Children's responses about tentativeness of the scientific knowledge in meteorology domain at the end of the camp were modeled in Figure 6. Almost all children stated that meteorologists cannot be sure about the computer models of weather patterns. The main reasons for this were similar to the ones at the beginning of the camp. They again understood the question as weather forecasts. Children thought that weather reports were predictions and the nature of weather was dynamic. In addition to these reasons, half of the children also realized the importance of data in meteorologists' decisions. Children began to think that meteorologists would have limited data and weather reports depend on the amount of the data meteorologists had.

They (meteorologists) make predictions based on their data. For this reason, they are not sure about them. But, it would be true. Because, they make these predictions by observing and searching. In other words, they talk based on data. (Zehra)

Three children stated in general terms that scientific knowledge is tentative as a reason for meteorologists being not certain about computer models of weather patterns. These three children seemed to generalize tentative NOS to every domain and use this as reasoning for deciding about the tentativeness of any scientific knowledge. Only two children thought that meteorologists can be certain about the computer models of weather patterns, because meteorologists make detailed measurements and they use high technology.

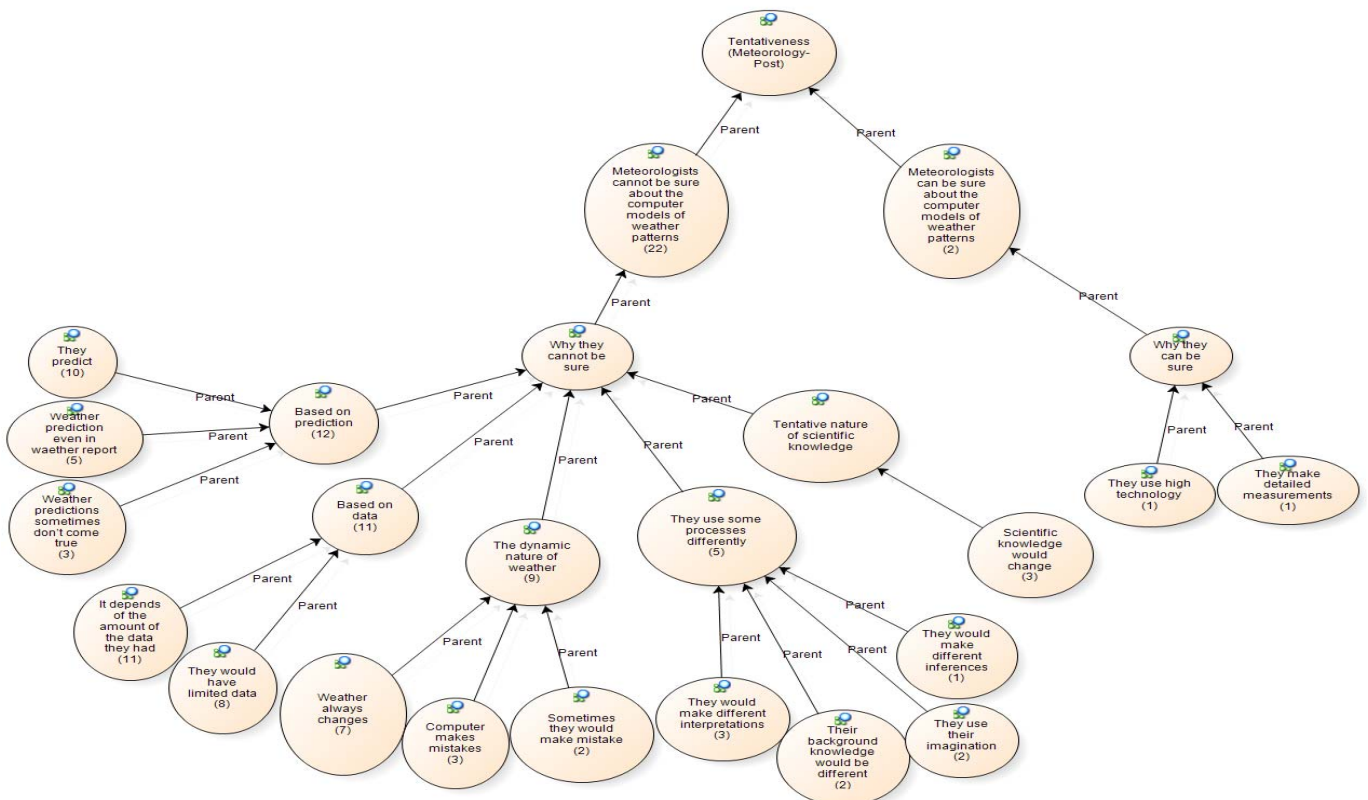


Figure 6. Children's views about if meteorologists would be certain about the computer models of weather patterns (post)

In summary, children's ideas about the tentativeness of scientific knowledge that meteorologists develops were mainly affected by weather forecasts and dynamic nature of weather at the beginning and end of the camp. The number of children thinking that meteorologists can not be sure about computer models increased from 16 to 22. In addition to this increase in the number of children accepting tentativeness of scientific knowledge in meteorology domain, some of the children started to base their explanations on data that meteorologists have. They indicate that the data they had would be limited or the data they have would change so thus knowledge about weather change. Three children generalized tentativeness of scientific knowledge to any kind of scientific knowledge. These three positive developments were observed in children's ideas from beginning to the end of the camp.

Conclusions and Implications

The science camp program which aimed at introducing NOS to the children developed children's view about tentative NOS. Children better explained why scientific knowledge changes at the end of the camp. In addition to the technological inventions, they realized the importance of the amount of data and the addition of new data in explaining the change in scientific knowledge. In addition, children also became able to explain how the scientific knowledge changes. At the pre-test, children could not explain how the scientific knowledge changes, they just said that new knowledge is added to available knowledge. But at the post-test, children focused on the collection of the new data, the amount of the collected data, and the change in data or its interpretation in their explanations of how scientific knowledge changes.

Although children determined the tentativeness of the scientific knowledge based mainly on the nature of the context (not being able to see dinosaurs, and the dynamic nature of weather or weather forecasts) at the beginning of the camp, they began to determine the tentativeness of the scientific knowledge based mainly on the data (the amount of the data and interpretation of the data) at the end of the camp. More children realized the tentativeness of scientific knowledge in all domains at the end of the camp.

It would be concluded that camp program consisting of guided-inquiry and explicit NOS activities were effective in developing children's views about tentative NOS. Explicit NOS activities were proved to be effective in developing children's ideas about NOS (Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006; Khishfe, 2008). But, combining explicit NOS activities with guided-inquiry helped children better understand the process of scientific knowledge construction from data to scientific knowledge. This affected children's explanations in the tentativeness of scientific knowledge which is evident in their explanations of tentativeness of scientific knowledge based on data. Such explanations are more detailed explanations including the process of scientific knowledge construction.

Although not all of the children reached the general idea that all kinds of scientific knowledge at any domain are tentative, it progressed toward this ideal end point. Context of the question affected their ideas about the tentativeness of scientific knowledge, but this is in accordance with the reality. Tentativeness of scientific knowledge is a complex issue. Although all scientific knowledge is tentative, degree of tentativeness depends on many factors such as the subject area, amount of research conducted in any subject, e. t. c. Thus, it was interpreted as normal for children's ideas affected by the context of subject area. But, as they learn more about tentativeness of scientific knowledge in different areas, they would reach the generalization that all kinds of scientific knowledge are tentative, but reliable regardless of domain.

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EVALUATING THE LEARNING POTENCY OF HISTORICAL AND EPISTEMOLOGICAL RELEVANT DIALOGUES

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Abstract

In this study we make a research contribution in the field of history and nature of science as a basis for learning physics. Dialogues have always been used as a media for instruction throughout the history. However, we chose to create fictional dialogues on Goethe-Newton and Newton-Huygens-controversies about optics. Goethe's critique focuses sharply on traits in Newton, which are characteristic features of modern natural science. In the developed dialogues authentic source material is used. The project is also a contribution to empirical research on multimedia learning, since the dialogues are designed to be presented in a computer learning environment and was evaluated in an empirical study. Physics teacher students in their second year of study show astonishing poor knowledge about the subject of the dialogues. Therefore factual information is given, to understand the core of the controversy. As evaluation data show students are interested in the multimedia program and ask for more information about other controversies in science. 'Scientific dialogues' may open the door for interest in science in general, because science learning should be more than a pure accumulation of facts, but rather an introduction into the nature of science.

The efficiency of dialogues for learning processes Introduction

Throughout the history of science dialogues played an important role as media for instruction purposes. Early examples are Platons Timaeus as a theoretical speculation on the nature of the physical world in the form of a Socratic dialogue, written 360 BC, or Galileo Galilei's Dialogue Concerning the Two Chief World Systems from 1632. There is some evidence that learning processes can be improved by dialogical texts.

In our project we refer to the book Thinking and Speaking (Vygotsky 2002), where Vygotsky establishes the explicit and profound connection between speech - both silent inner speech and oral language - and the development of mental concepts. In the last years the role of language in general as "a tool to facilitate thinking and plausible reasoning, to make sense of events in the natural world, and to solve communication problems," (Yore et al 2003) has been widely recognized.

In another study our research group tried to find out how narratively and dialogically arranged texts influence knowledge about geomagnetism. Pierre de Maricourt (13th century), Christoph Columbus (15th c.) and William Gilbert (16th c.) join a fictive meeting at a roundtable in a multimedia environment to discuss about magnetic declination. An evaluation study in grade 10 (age 15) proofs significant learning effects and desirable changes in views about the nature of science (Kasper 2007).

Based on promising results of studies in our group and elsewhere, we turned to do some research on the famous Goethe - Newton and Newton - Huygens controversies in the field of optics. This could be as well a fruitful contribution to the "nature of science debate".

The Goethe – Newton and Newton – Huygens controversies on optics

Colours in their origin and expression are a natural phenomenon of impressive variety and beauty. The introduction to the theory of colour in physics education is, in contrast, often designed as a presentation of the conceptual taxonomy of the world of colours which has accumulated over the three hundred years since Newton.

Routine haste and scientific logic have obviously dulled the approaches to colour through perception. If, however, we are concerned that knowledge should remain closely linked to the whole being of the learner and the learner's original relationship with nature, in considering the archetypal phenomenon of dispersion, then we may be permitted to be sceptical with regard to causal analysis paradigms. It is not a matter of method or of scientific accuracy. What follows is a matter of different views of nature, of different views of the world.

As modern science, according to Heisenberg (1941), restricts itself to a study of objective reality, it must refrain from the subjective, must disregard us as human beings with our reasoning and actions. Heisenberg ascertains that science is not concerned with the world as it offers itself to us, but with a dark background of this world which we bring to light by our experiments. We may perforce accept this separation of reality, this division of human knowledge for the physicist, but learners need bridges from the very beginning.

And in view of the ecological crisis we currently face, the problem of separation has become more immediate than ever. Heisenberg maintains that Goethe's struggle against the colour theory of physics must be continued today on a wider front, and that recognition of modern physics cannot hinder the natural scientist from following and extending Goethe's way of observing nature.

Developing multimedia programs “Goethe meets Newton” and “Newton meets Huygens”

Based on this theoretical background we started our learning project in the context of physics education. Knowledge on the nature and history of science seems to be essential for substantial understanding, as physics is much more than an aggregation of its results. From our point of view, a constitutional component of physics as a scientific discipline is the process of investigation. Being aware of this, physics becomes a lively activity and hopefully appears more interesting to more students – especially to girls and women.

To prove this hypothesis, we developed the multimedia learning environment “Goethe meets Newton”. It is an example for optics teaching that is sensible to the issue of nature of science and therefore suits the purposes of our research project in physics education.

The multimedia learning environment comprises the famous historical controversy between Newton and Goethe, who was born 22 years after Newton died. In a fictional situation the two protagonists are brought together around a table. Based on historical references – Newton's “Optics” (1704) and Goethe's “Farbenlehre” (1810) – a dispute was composed (fig.1) and arranged in a multimedia learning environment (Mikelskis 2005).



http://www.uni-potsdam.de/db/physik_didaktik/files/goethe.pdf?131,95



Figure 1: Multimedia dialogue “Goethe meets Newton”

In our Potsdam physics education group we could base on our previous research and development results on multimedia learning (Mikelskis 2000). In the nineties we could recognize the booming international multimedia research scene, full of hope and confidence (Mayer 2003, Schnotz 2003, Linn/Davis/Bell 2004).

But now we are entering a phase of realistic self-assessment. Further research should focus on empirical evaluation studies with didactical relevant examples for science education. Our Goethe – Newton example is only one of many possible.

The Goethe-Newton-antagonism in colour theory is an example for different views of nature and perhaps – in the end – for different views of the world. However its topic is not only a question of right or wrong!

Newton’s work about optics and colour was inspired by Descartes, Boyle and Hooke and based on his publications on mathematical methods, geometry and principles of mechanics. In his three crucial experiments he claimed:

1. Refraction and dispersion of thin rays produce a spectrum band.
2. Condensation of the spectrum band by a lens delivers again white light.
3. A spectral colour can be refracted again but it cannot be further dispersed.

In our multimedia learning environment “Goethe meets Newton”. Newton and Goethe explain their position (see the following example, fig.2 and fig.3).

NEWTON

In a very dark Chamber, at a round Hole, about one third Part of an Inch broad, made in the Shut of a Window, I placed a Glass Prism, whereby the Beam of the Sun's Light, which came in at the Hole, might be refracted upwards toward the opposite Wall of the Chamber, and there form a colour'd Image of the Sun.

The Axis of the Prism was in this and following Experiments perpendicular to the incident Rays. About this Axis I turned the Prism slowly, and I saw the refracted Light on the Wall, or coloured Image of the Sun, first to descend, and then to ascend. Between the Descent and Ascent, when the Image seemed Stationary, I stopp'd the Prism, and fix'd it in that Posture, that it should be moved no more.

This Image was Oblong and not Oval, but terminated with two Rectilinear and Parallel, and two Semicircular Ends. On its Sides it was bounded pretty distinctly, but on its Ends very confusedly and indistinctly, the Light there decaying and vanishing by degrees.

The Light of the Sun consists of Rays differently Refrangible.

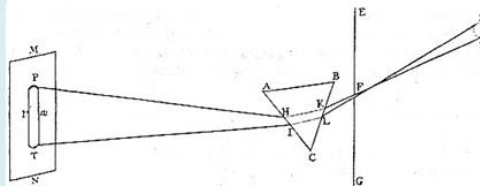
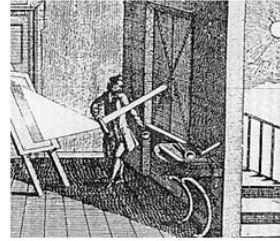


Figure 2: Multimedia dialogue “Goethe meets Newton” – example from Newton

GOETHE

The luminous form is coloured so much more strongly by prisms than by media with parallel sides.

At each of the two opposite boundaries an opposite effect arises in a narrow angle, and widens along the extension of this angle as it traverses the room.

In the direction of the luminous form's displacement a violet fringe advances into the dark, while a narrow blue border remains at the boundary.

From the other side a yellow fringe advances into the light and a yellow-red border remains at the border.

For a long while the center of the form remains without color, especially with media of little density and mass.

At last the opposite fringes and borders will reach one another, and a green color will appear in the center of the luminous form.

The refraction is the true basis of Newton's theory. But I confess that colour effects are not generated by refraction alone! A second necessary condition is, that refraction acts on an image by shifting it. An image is created merely by its boundaries, and these boundaries are not taken into account by Newton.

No image will become colourful in the middle, unless the coloured boundaries touch or overlap each other.

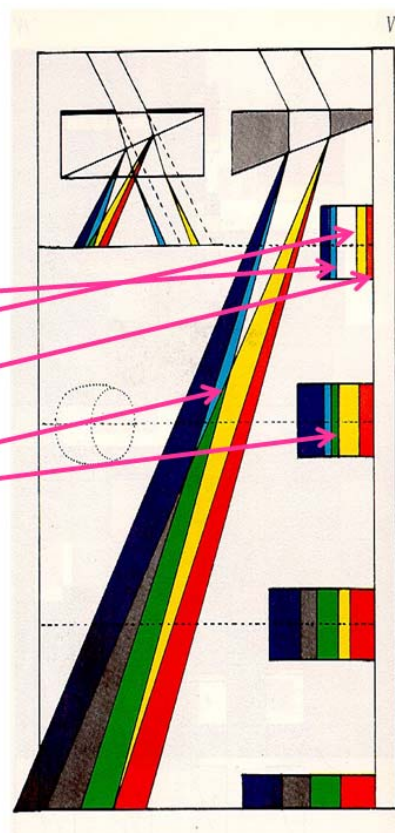


Figure 3: Multimedia dialogue “Goethe meets Newton” – example from Goethe

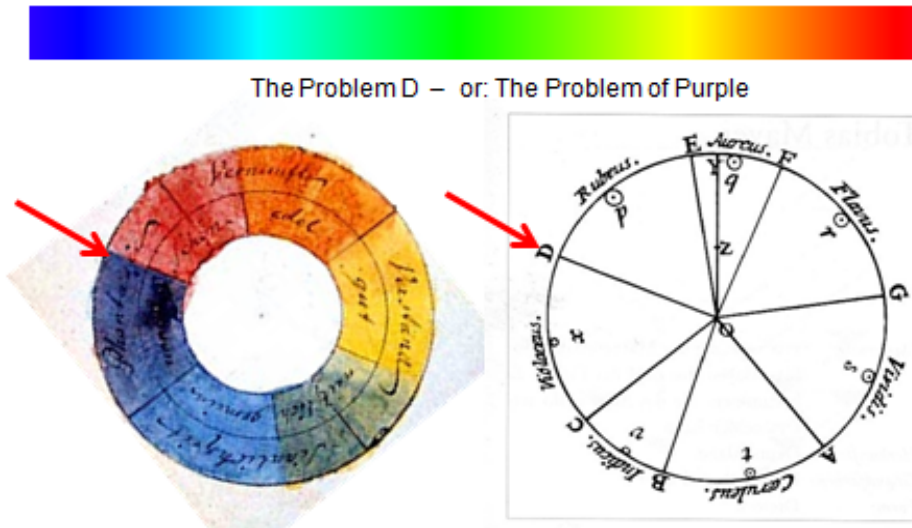


Figure 4: Newton's spectrum and colour circle of Goethe (left) and Newton (right)

In the end Newton and Goethe summarize their theory in colour circles. They are quite similar, but have one important difference (see arrow in fig. 4).

Design of evaluation and selected results

To prove how students learn with our multimedia program (fig.6) we designed a study with physics teacher students (fig. 5). In the pretest we diagnosed exemplarily their knowledge in colour optics. In the posttest we asked for the evaluation of the program. In further research more detailed questions may be raised. In the presented study we focused on the feasibility question.

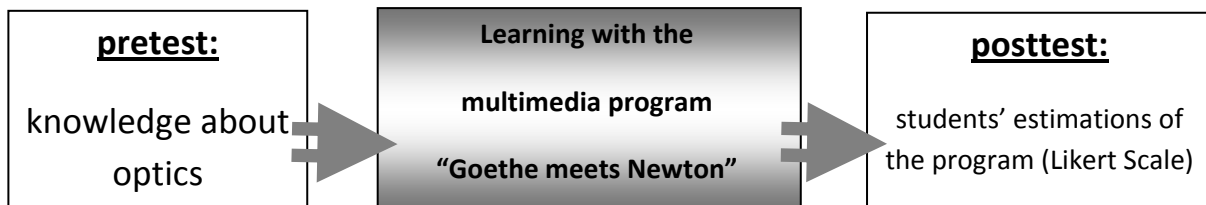


Figure 5: Design of the study (N = 104 physics teacher students, second year of study)



Figure 6: physics teacher students working with the multimedia learning environment

The five items in the posttest part 1 (fig 7) prove the overall acceptance of the program. The language is understandable and text and picture fit together. But the author should reduce the amount of text, a problem of most multimedia producers. One reason for this response could also be the short time given to the test persons. The item “language of program” shows the biggest standard deviation. This proves obviously the large variety in the prerequisites of the students and gives reasons for differentiations in the final version of the program.

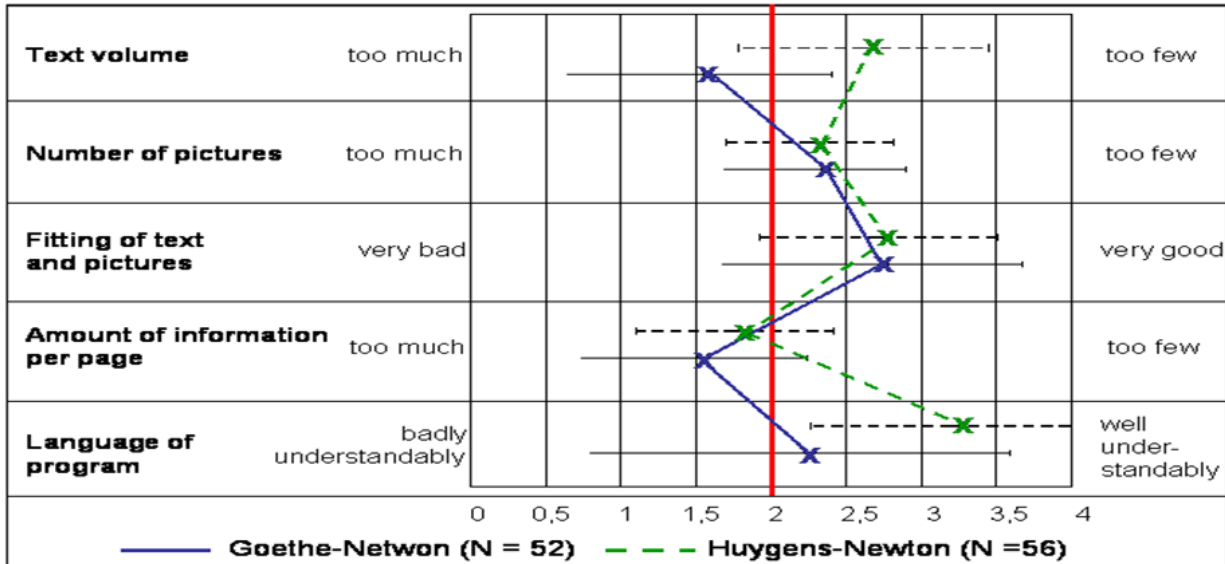


Figure 7: Students' estimations of the program (posttest – part 1)

The answers in the posttest part 2 (second item) correspond with the first two items in the pretest (figure 8), indicating that nearly no student knows anything about the Goethe-Newton-controversy. This is astonishing in Germany, the homeland of Goethe, the famous poet. But his monumental work in the field of science is not known to a broader public.

Although students do not know very much about the subject, they obviously prefer the Newton position. But hopefully students require more information and are interested in further science controversies.

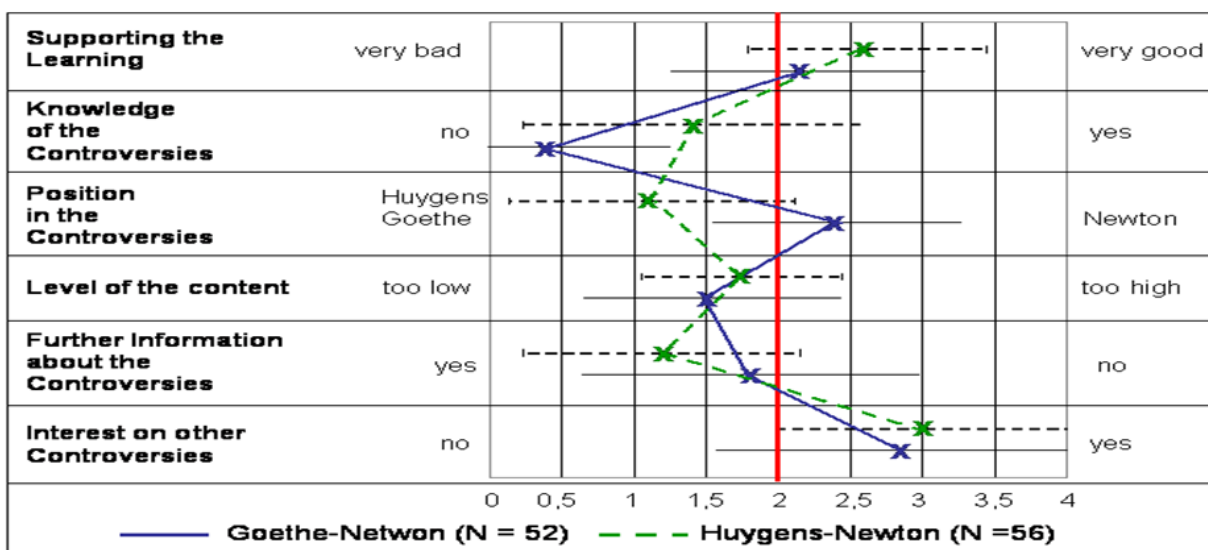


Figure 8: Students' estimations of the program (posttest – part 2)

A second aim of the study was to get information about the preknowledge in the domain of colour optics, related to the multimedia dialogue (fig. 9).

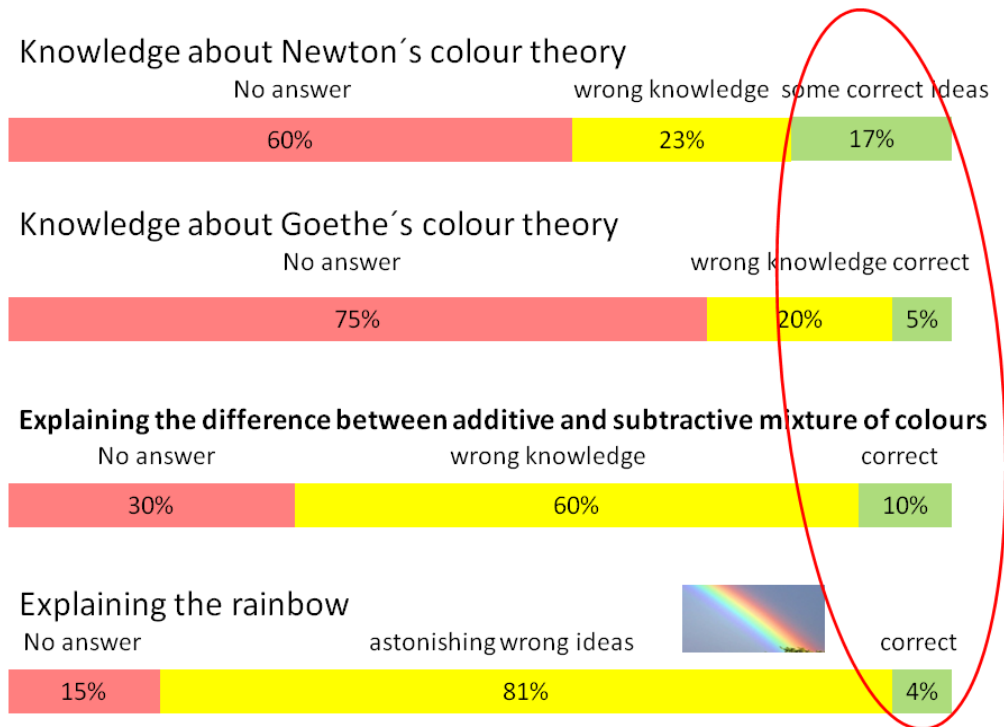
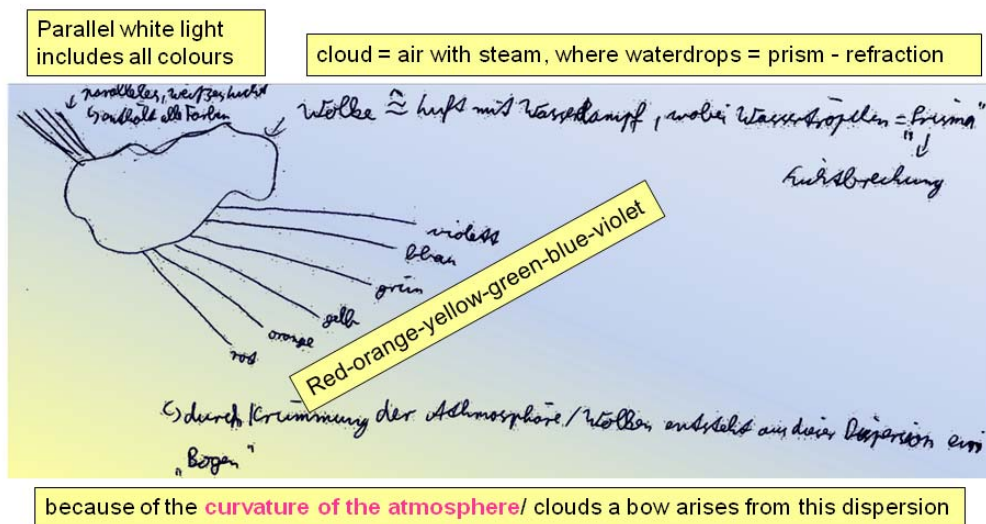


Figure 9: Some Information about the poor preknowledge

The paper and pencil test shows more details about the students knowledge (fig. 10 and 11). Only one (!) of all 104 students gave a correct answer in explaining the rainbow.

Explain by describing and sketching the origination of a rainbow!



Where is the observer ?

Figure 10: Where do the colours come from?

Explain by describing and sketching the origination of a rainbow!

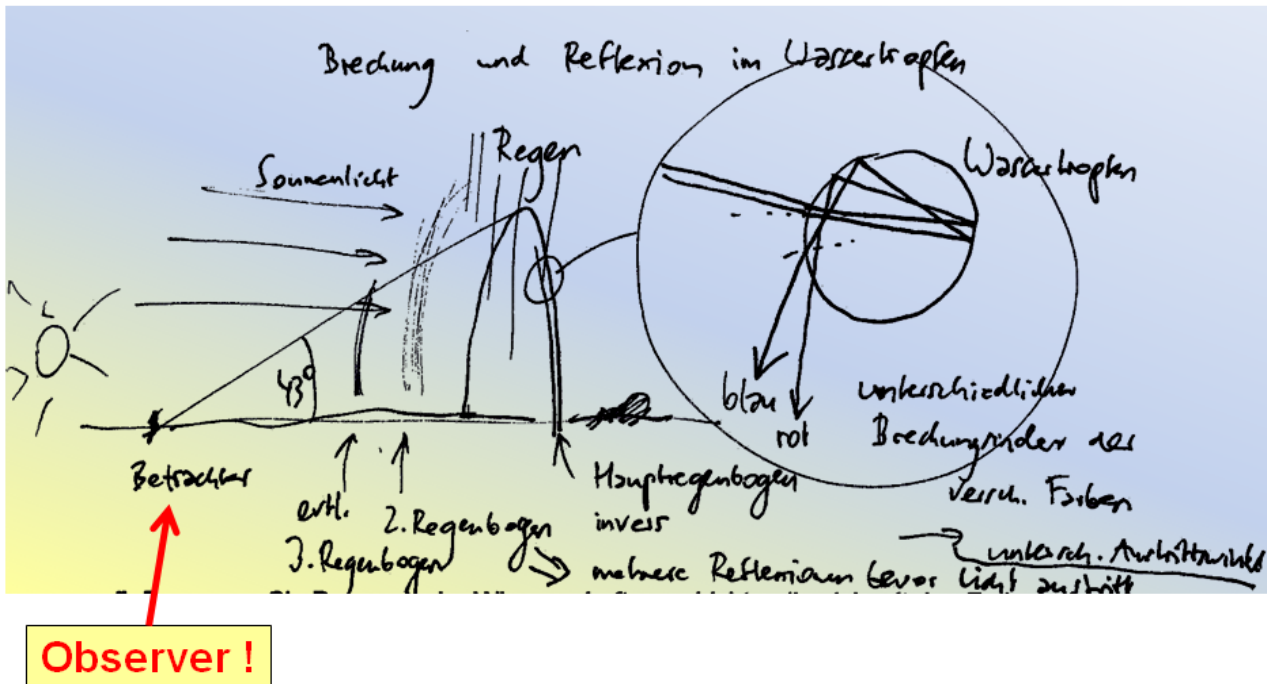


Figure 11: The only correct answer

Conclusion and outlook

Almost nothing is known by 2nd year physics teacher students about the mentioned subject area of our historical controversy or its implication for the nature of science. Whether this indicates a deficiency of our physics teacher education program needs further investigation, but seems likely.

In our evaluation the empirical data prove the quality of the learning program for physics teacher students in their second year of study. The learning program allows knowledge acquisition in the subject in general and is perceived as well designed by the students. To have contrasting results, it would be worth, to repeat the study with pupils in upper school classes, university students at the end of their study or even experienced physicists.

Fictive dialogues on other subjects can be and have been produced on the basis of these results of our study (see e.g. Kasper 2007) in order to check for domain specific results. We consider this approach to be a promising opportunity to improve certain students' interest in science and to build a bridge between the "two cultures" (Snow 1993)

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PART 3
INFORMAL – OUTDOOR SCIENCE EDUCATION

EFFECT OF NATURE-BASED EDUCATION ON A CAMP ON CHILDREN'S ATTITUDES TOWARD ENVIRONMENT AND THEIR IDEAS ABOUT HUMAN-NATURE INTERACTION

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Abstract

The purpose of this study was to find out the effect of having first-hand experiences at a science camp conducted at the nature on children's conceptions of human-nature interaction and changing their attitudes toward the environment. Twenty-four 4th and 5th graders participated to the camp. The camp program consisted of observations of plants, animals, and other living and non-living organisms. A questionnaire consisting of 10 open-ended questions (but only two questions were discussed in this study) was developed by the researchers and an attitude scale developed by Gokce, Kaya, Aktay and Ozden (2007) were implemented as pre- and post-test. The children were interviewed on the questionnaire responses to enrich the data. The results showed that children thought that human affect the nature negatively at both pre- and post-test. Negative human effects were more about polluting environment, and disturbing plants and animals. There were slight increases in the negative and positive effects of human stated by the children at the post-test. They were more aware of direct human pollution than industrial pollution at both pre- and post-test. Their attitudes were already very positive at the pre-test and increased slightly at the pos-test, but it was not statistically significant.

Introduction

Human effect was the main reason for many environmental problems. Thus, the best solution would be educating people about environmental problems and its consequences. This is done in most of the environmental education studies (Yilmaz, Morgil, Aktuğ, & Gobekli, 2002; Bozkurt, & Cansungu (Koray), 2002). In addition to such studies, interacting with the nature and understanding its processes and interdependence of these processes would also be beneficial (Zandvliet, 2007). Because, people understanding nature holistically would be more sensitive toward it (Eagles & Demare, 1999) and this sensitivity would form a base for responsible behaviors regarding environment and nature.

Nature education studies are usually done at natural sites. Field trips to the nature, visits to nature centers, museums, parks, botanic gardens and zoos (Knapp & Poff, 2001; Ballantye & Packer, 2002) are some examples of nature education. Nature education as a camp is another option. Nature education camp projects have also been conducted by Science and Society department of Scientific and Technological Research Council of Turkey (STRCT) for the last decade. These nature education camp projects are usually implemented with undergraduate students from different fields and pre-service and in-service teachers. The same institution also supports science camp projects for children. In these science camp projects, children learn science, some specific subject of science or nature. This study was conducted at one of such science-camp projects. Children participated to the science camp had nature-based education at a camp site. They had first-hand experiences at the nature and followed a program consisting of observations at the nature. They shared their observations with their friends.

Most of the environmental studies focused on determining on children's attitudes and behaviors toward environment and their knowledge about the environment rather than children's conception of environment (Rickinson, 2001). In recent years, children's conception of environment was searched by applying qualitative

methodologies (Kenney et al., 2003; Keinath, 2004; Shepardson et al., 2007). In this study, children's conception of nature was searched in general, but their ideas about human effect on the nature and environmental problems are presented in this paper.

Children attitudes toward environment were searched in many studies (İşyar, 1999; Yılmaz, Boone, & Andersen, 2004; Atasoy, 2005; Alp, Ertepinar, Tekkaya, & Yılmaz, 2006; Erol & Gezer, 2006; Uluçınar Sağır, Aslan, & Cansaran, 2008), because attitudes affected people's behaviors. Researchers also wondered how children's attitudes toward environment were at the beginning of the camp and how they changed throughout the camp. Although attitudinal changes take time and duration of the camp was short, it was still a wonder for researchers.

The effect of the camp on children's attitudes toward environment and their ideas about human-nature interaction was searched by applying a questionnaire developed by the researcher and an environmental attitude scale developed by Gokce, Kaya, Aktay and Ozden (2007). The children were also interviewed on their questionnaire responses to better understand their ideas. Two questions from the questionnaire related to human effect on the nature and environmental pollution and attitude scale results are presented in this paper.

Rationale

Environmental education is mostly done through classroom activities in Turkey. Field trips could rarely be done. In addition, most of the classroom activities are about environmental problems. But, interacting with nature and making observations at natural sites would better help children to understand nature and natural processes. This type of nature education would also develop positive attitudes toward environment.

Summer science camp is an informal learning environment and such learning environments would be more interesting and motivating for children. Camp programs are generally short, but heavy. If the total hour is considered, one week camp program would correspond to almost a two-month application in the schools. Thus, science camps would be good opportunity for environmental education.

Method

The purpose of the study was to find out the effect of having first-hand experiences at the nature on children's conception of human-nature interaction and their attitudes toward environment. For this purpose, a summer science camp was organized and applied. The science camp was named as Three in One: Nature, Science and Children Summer Science Camp First Term and applied on June 25-July 02, 2008 in Bolu, Turkey. The camp site was a holiday village next to a forest. The project-team mainly consisted of science educators and all of them stayed at the camp with the children throughout the camp. Participants were 24 elementary school children (9 girls and 15 boys). They were 4th or 5th grade. Participation was voluntary. The participants were chosen only according to their desire and interest in doing research at the nature.

The camp program was developed by the researchers and presented in Table 1. Morning and afternoon sessions were allocated to observation sessions. In these sessions, the children observed various plants, animals and other living and non-living organisms in their habitats at the nature. The observations were sequenced from close environment to distant environments. Observations also sequenced from big organisms to small organisms. They shared their observations in the end of each observation session. In the evening sessions, they sometimes played ecology games and sometimes did interesting activities such as painting and space observation. In each evening session, they evaluated their experiences during the day and reflected their feelings.

Table 1. The science camp program.

Hours	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Morning Sessions (9am-13pm)		Pre-test application (Questionnaire about the nature, and interviews on the questionnaire)	A field trip around the camp area (Observations at many stations, such as trees, plants, butterflies, frogs and puddle)	Ecology Games II (A simulation game about habitat of deer and its carrying capacity. Providing the data from the game and graphing)	Ecosystems around the camp (Visiting forest, puddle and teaching ecological concepts at the nature)	Distant Ecosystems (Watching documentary about rainforests, deserts and poles) Observation of ants and their behavior	Observing birds around the camp (area) Sharing and discussing the role of birds in eco-system)	Post-test application (Questionnaire about the nature, and interviews on the questionnaire)
Afternoon Sessions (3 pm-7pm)	Coming to the camp	Mathematics at Nature (Fibonacci numbers, Golden Spiral)	Sharing and discussing the field trip observations	Nature and Art (Designing a photograph frame with the materials from the field trip. Listening to four season symphony of Beethoven)	Eco-system of a Lake, Abant (Observing biological diversity in and around the lake)	Sharing and discussing the role of the ants in the eco-system	Observing in detail (Observing ants, insects, worms under the stereoscope and leaves under the microscope)	Presenting the learning products during the camp to parents Certification and ending the camp
Evening Sessions (8pm-11pm)	Welcome party	Evaluation Getting rest	Ecology Games I (Guess which animal is it?) Evaluation Getting rest	Forming small groups Evaluation Getting rest	Creative Painting (Painting a T-Shirt) Evaluation Getting rest	Sharing and discussing of observations done during today Evaluation Space Observation (Observing constellations)	Ecology Games III (Eco-systems jury discussing on considering whether Abant Lake should be a national park or not) Evaluation-Party	

In order to determine the change in children’s ideas about nature in general, a questionnaire developed by the researchers was applied at the beginning and at the end of the science camp. It included ten questions about the nature and the natural processes. Semi-structured individual interviews on their questionnaire responses were also conducted to deepen the data. The data from following two questions are presented in this paper:

- What is the effect of human on the nature?
- What do you know about environmental pollution? How such pollutions effect the environment?

Qualitative data analysis for these questions was done through coding the data and inductive classification of the codes. Interpretive analysis (Simsek and Yildirim, 2006) was applied. After the codes were organized, they first described and interpreted. In addition, environmental attitude scale for elementary students (Gokce and others, 2007) was applied at the beginning and at the end of the camp. The attitude scale consisted of 34 items and three-point Likert scale (agree, undecided, don’t agree). Cronbach alpha reliability was reported to be .87 (Gokce and others, 2007). Quantitative data analysis of the data from the attitude scale was done by descriptive statistics and Wilcoxon Signed Ranks Test for the comparison of pre- and post- test means.

Results

The data related to first question at the beginning of the camp was presented in Figure 1.

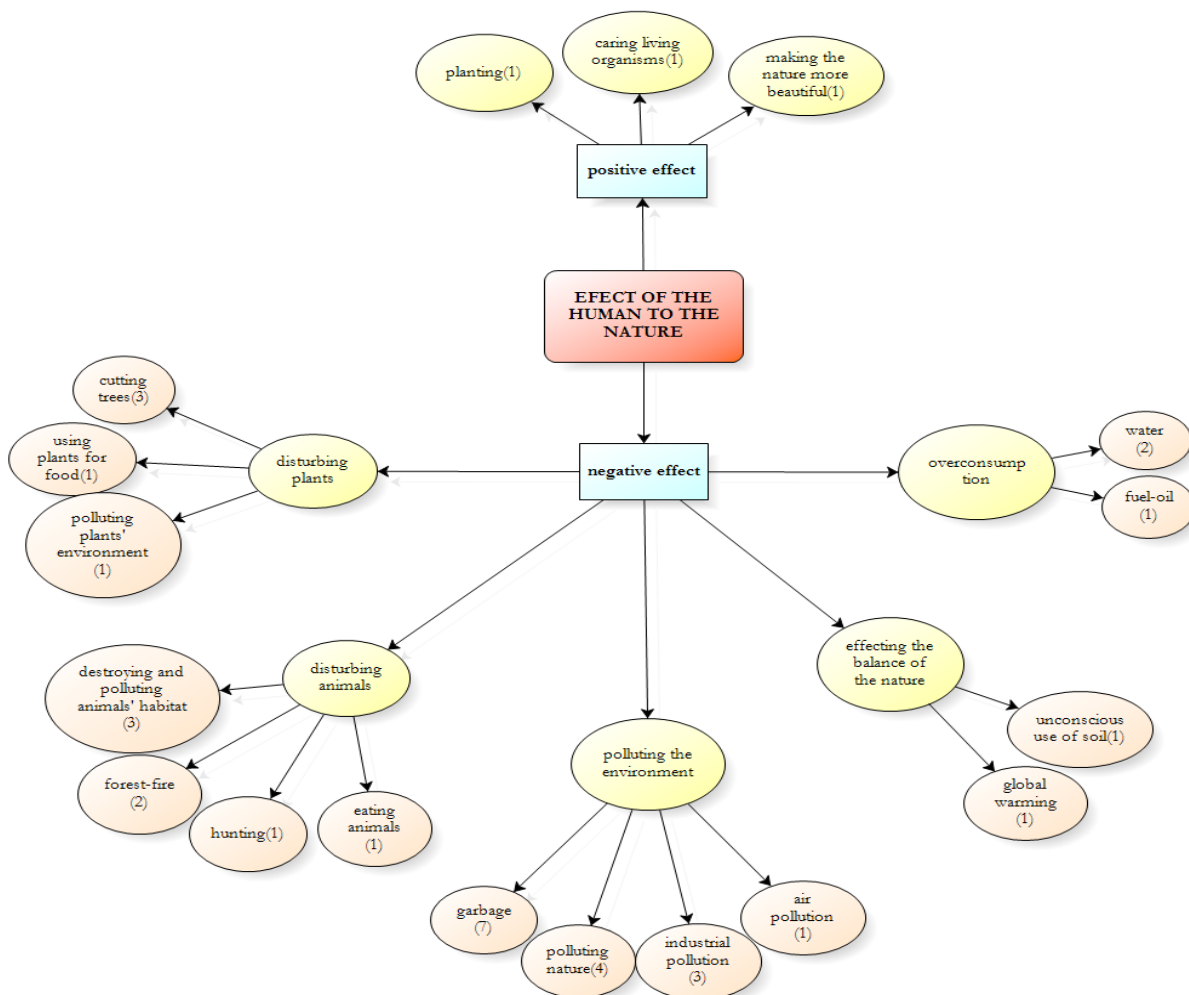


Figure 1. Children’s ideas about the effect of human on the nature at pre-test.

Positive effects of human on the nature were rare (frequencies in parentheses); planting (1), caring for living organisms (1), making the nature more beautiful (1).

On the other hand, negative effects were severe and categorized mainly as disturbing plants, disturbing animals, polluting environment, affecting the balance of the nature, and overconsumption. They meant by disturbing plants, cutting trees (3), using plants for food (1), and polluting plants' habitats (1). Disturbing animals was indicated as destroying and polluting animals' habitats (3), forest-fire (2), hunting (1), and eating animals (1). Some of them stated that people pollute the environment by throwing waste on nearby environment (7). A few of them were aware of industrial pollution (3) and air pollution (1). Overconsumption of water (2) and fuel-oil (1) were also stated. Only two children indicated that human affect the balance of the nature by global warming (1) and unconscious use of soil (1).

At the post-test, the children's responses to the same effect question was coded and organized as in Figure 2.

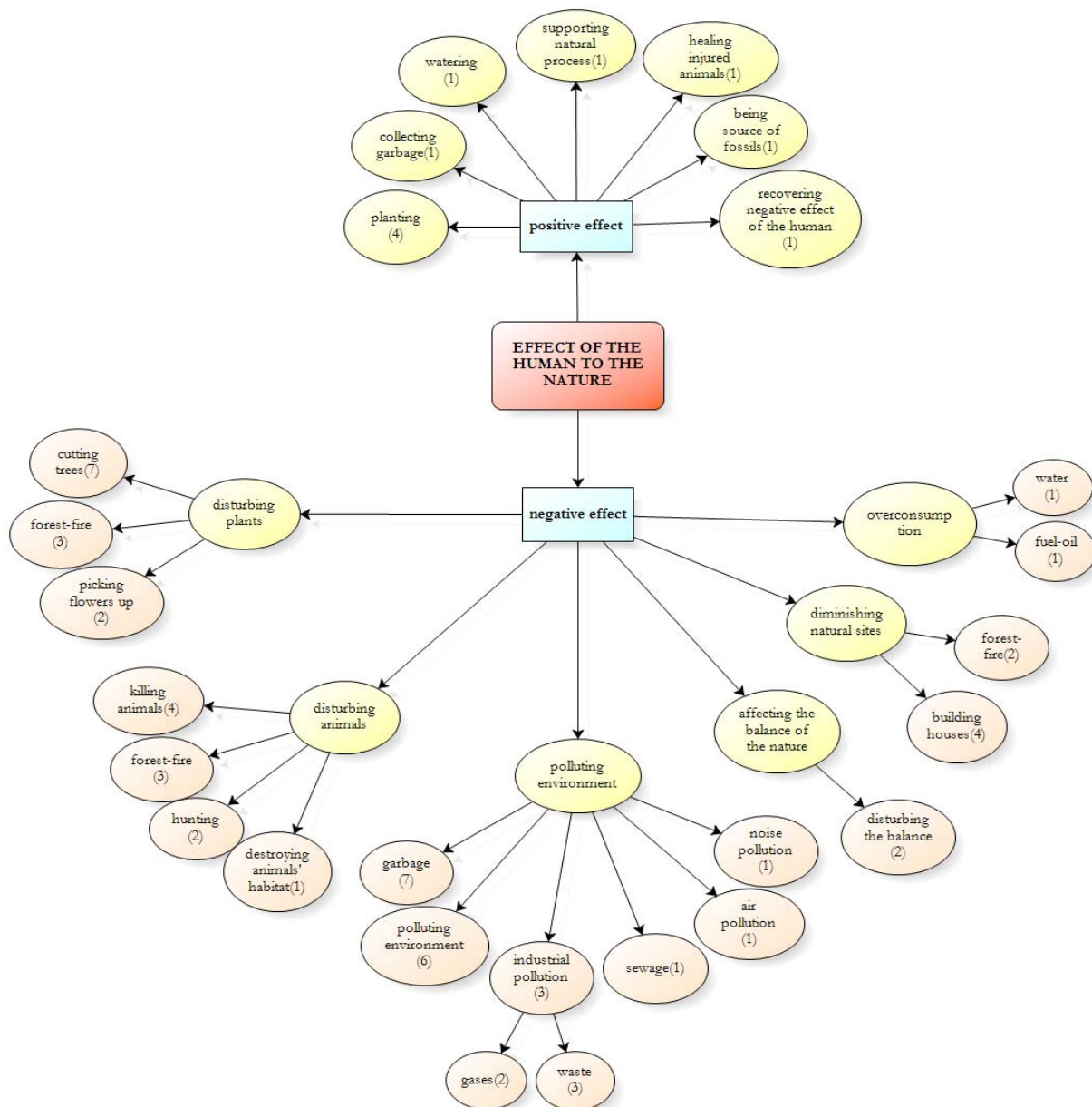


Figure 2. Children's ideas about the effect of human on the nature at post-test.

Positive effects of human on the nature were again less than negative effects. Positive effects of human on the nature increased from beginning to the end of the camp. They were planting (4), collecting waste (1), watering (1), being a part of the nature and help its process (1), healing injured animals (1), being source of fossils (1), recovering negative effect of human on nature (1).

Negative effects of human on the nature were very similar to the ones at the pre-test. They were disturbing plants, disturbing animals, polluting environment, affecting the balance of the nature, overconsumption, and diminishing natural sites. Only diminishing natural sites category was added at the post-test. They thought that people disturb plants by cutting trees (7), forest fire (3), picking flowers up (2) and disturb animals by killing animals (4), forest fire (3), hunting (2), and destroying animals' habitat (1). Their ideas about the pollution of the environment were again similar: garbage (7) being the most known environmental pollution, they also stated industrial pollution (3), air pollution (1), sewage (1), and noise pollution (1). Two children stated that people affect the balance of the nature. Overconsumption of water (2) and fuel-oil (1) was again stated by a few children. Additionally, some of the children indicated that people diminish natural sites by building houses (4) and forest-fire (2).

The children were also asked what they knew about environmental problems and how they affected the environment. They mostly focused on environmental problems in their responses to these questions. The coding scheme of their responses to this question at the beginning of the camp was presented in Figure 3.

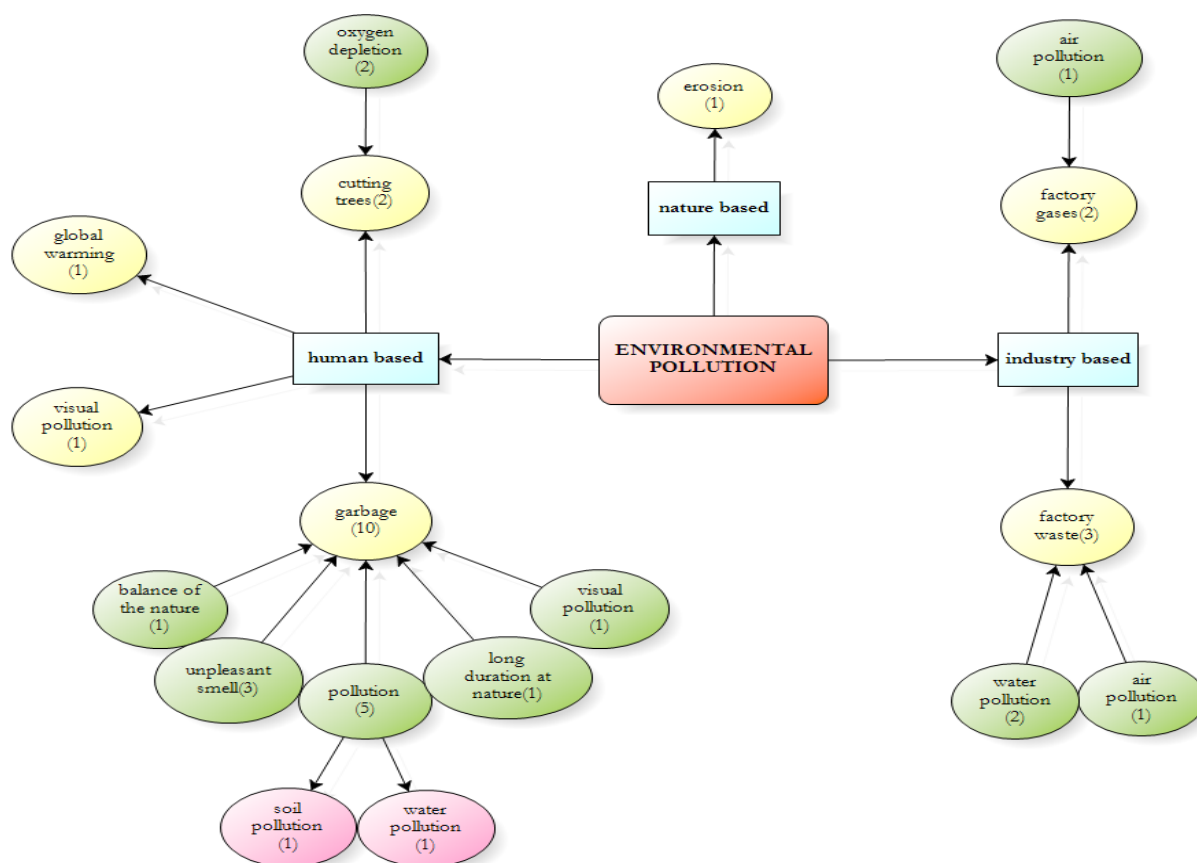


Figure 3. Children’s ideas about the environmental pollution at pre-test.

Their responses were categorized as three main categories; human based, industry based and nature based environmental problems. Human based pollution was considered as direct human effect such as garbage. Industrial pollution was also a human effect, but it was considered as indirect human effect and thus separately coded into a different category. The children were more aware of human based environmental problems and garbage (10) was

the most known. They were also aware of that garbage pollutes the environment (5), caused unpleasant smell (3), and visual pollution (1), stay long at the nature (1), and affect the balance of the nature. Cutting trees was stated by two children and they stated that less oxygen is produced when the number of trees was decreased. Only one child stated global warming and visual pollution as environmental pollution. Interestingly, erosion was stated as an environmental problem by one child. Industry based environmental pollution were factory waste and gases. They were related to air and water pollution.

At the end of the camp, they stated more environmental pollution types than they did at the beginning of the camp (Figure 4). They again more aware of human based environmental pollution than industry based environmental pollution. Garbage (19) was again the most known human based environmental pollution. They similarly stated that garbage polluting environment (9), cause water pollution (1), soil pollution (1), unpleasant smell (3), visual pollution (2), forest-fire (4), and global warming (1). They also stated that garbage stay long at the nature (4) and damage living organisms (3). The children stated more environmental problems than the ones at the beginning of the camp. Exhaust gases (4), light pollution (4), water pollution (2), air pollution (2), noise pollution (2), using deodorant (2), thinning ozone layer (2), unpleasant view (2), voice pollution (2), forest fire (1), and sewage (1) was the environmental problems emerged only at the end of the camp. In addition to increasing variety of environmental problems in children’s responses, they also reflected that they were more aware of the consequences of these environmental problems. The second level coding (green ovals) represent the consequences of environmental problems and development is evident when it is compared to the ones in Figure 3.

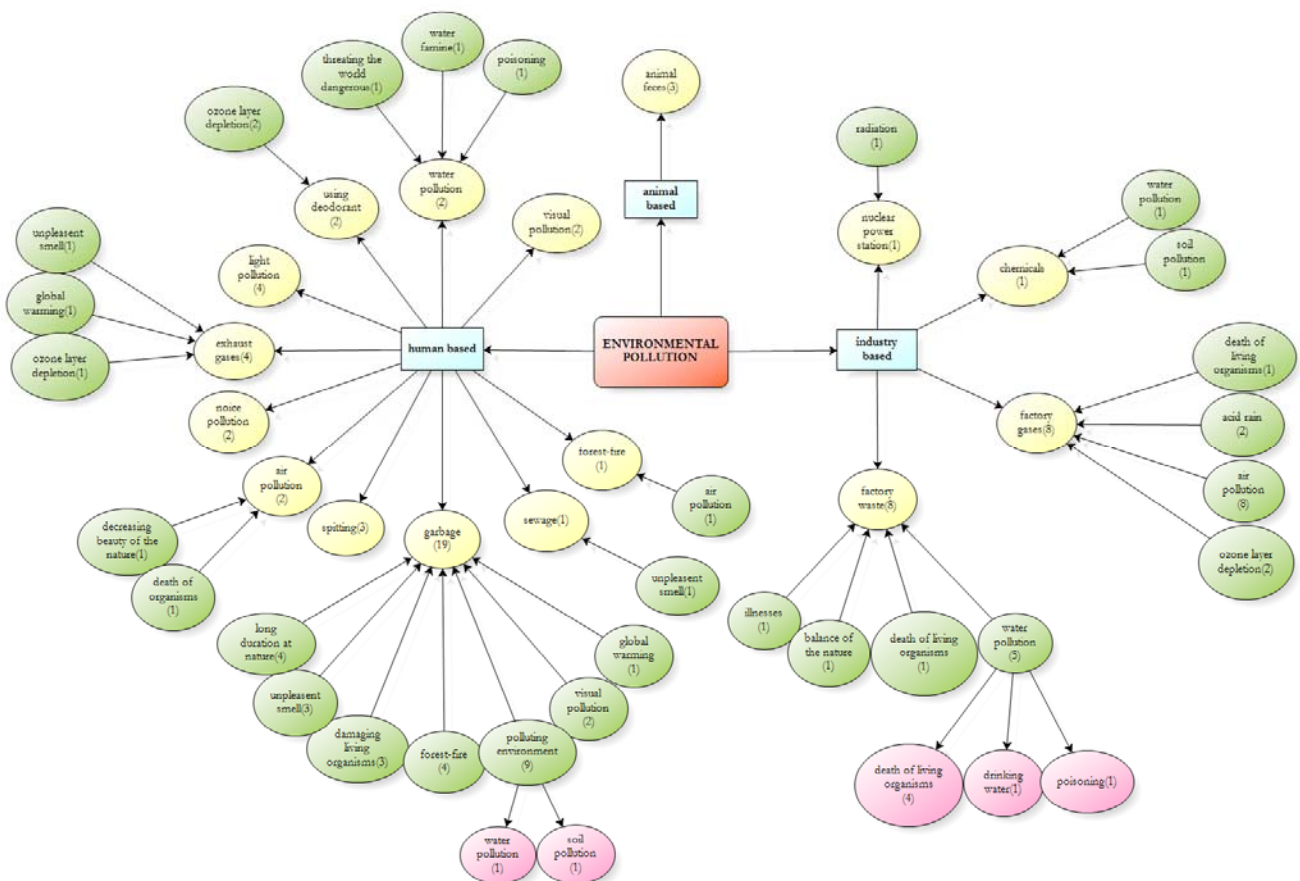


Figure 4. Children’s ideas about the environmental pollution at post-test.

Children's attitudes toward Environment

The environmental attitude scale (Gokce and others, 2007) consisted of 34 items and three-point Likert scale. Thus, possible maximum point from the scale was 102 and minimum point was 34. The scale was applied at the beginning and end of the camp. Descriptive statistics of the children's attitudes toward environment scale were presented in Table 2.

Table 2. Descriptive statistics of the children's attitudes toward environment scale

	N	Min.	Max.	X	SD
pre-test	24	84	99	92.20	4.41
post-test	24	88	100	93.66	3.84

There was a slight increase in the mean from pre- to the post-test. The children were already very close to positive end of the scale (3) at the pre-test ($92.20/34=2.71$) and get closer at the post-test ($93.66/34=2.75$). Mean scores at pre- and post-test were compared by Wilcoxon Signed Ranks Test and its results were displayed in Table 3.

Table 3. Wilcoxon Signed Ranks Test results

Pre- and post-test	n	Mean of Rank	Sum of Rank	z	p
Negative Rank	7	9.79	68.50	1.63*	0.101
Positive Rank	14	11.61	162.50		
Equal	3				

*Based on negative rank

The positive change in children's attitudes toward environment was not statistically significant. The reason for non-significant result from pre- to post-test would be small increase from pre- to post-test and ceiling effect. The children's attitudes were already high at the pre-test.

Conclusions and Implications

Unfortunately, children thought that human effect the nature negatively at the beginning and end of the camp. The most noticed negative effect of human on the nature by the children was garbage at the beginning and end of the camp. There was only slight increase in the negative effects of the human stated by the children from beginning to the end of the camp. Children's conception of human mostly affecting the nature negatively is in accordance with the reality. Although they were too young, they started to understand this reality.

The children had difficulty in finding positive effects. Positive effects rarely stated at the beginning of the camp, but increased and enriched a little bit at the end of the camp. Most of the positive effects stated were related to the human's positive interaction with their closest environment such as planting, caring for living organisms at the beginning of the camp and planting, collecting waste, watering, healing injured animals at the end of the camp. They were not aware of global positive human effect on the nature. On the other hand, some of them aware of global negative effect such as industrial pollution and air pollution at both beginning and end of the camp. This would be caused by teaching such global environmental problems through schools and media. On the other hand, global efforts to save the environment were rarely taught in such learning environments in Turkey. Only two children stated that human is a part of the nature and help its process and human recover negative effect of human on the nature at only end of the camp.

They stated human based pollution (especially garbage) more than industrial pollution at both beginning and end of the camp. This conception is the opposite of the reality which is industrial pollution is more devastating than human caused pollution. This would be caused by ego-centric view of the children and being close to human caused pollution types. Industry based pollution stated by children were mainly factory waste (8) and factory gases (8). Chemicals (1) and nuclear power station (1) was stated by two children. The children stated only air pollution and

water pollution as consequences of industrial pollution at the beginning of the camp whereas they were able to indicate more consequences such as acid rain (2), ozone layer depletion (2), and soil pollution (1), e.t.c. at the end of the camp. In summary, the children stated more and various pollution types at the end of the camp. In addition to increase in variety of pollution types, they better explained how these pollution types affect the nature at the end of the camp. Furthermore, some of them better recognized the effect of different pollution types on the living organisms at the end of the camp.

Nature-based education at the camp positively effected children's attitudes toward environment. Children's attitudes toward environment were already very high at the beginning of the camp and thus the increase was small and non-significant (ceiling effect). The reason for children being high attitudes toward environment would be the voluntary participation to the camp. They were highly motivated and formed a homogeny group regarding environmental attitudes.

Implications of the study for elementary science teaching would be introducing positive effect of human on the nature such as managing forests to form a healthy forest, saving some animals, e.t.c. Some documentary films would help for this purpose. Industrial pollution would be introduced as they growing up in order to help them understand its treating consequences.

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CONNECTING FORMAL AND NON-FORMAL ASTRONOMICAL LEARNING: AN INTEGRATED EDUCATIONAL PROGRAM USING AN INFLATABLE PLANETARIUM PERMANENTLY LOCATED IN A SCHOOL

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Abstract

This paper refers to an integrated astronomy education program for pre-primary and primary school students, which aims to bridge the gap between formal and non-formal learning, and to develop new science curriculum within museum education introducing methodological tools from the field of Cultural Historical Activity Theory (CHAT). The program, implemented on the occasion of the International Year of Astronomy 2009, is held at a school which was equipped for that purpose with an inflatable planetarium. It is now widely accepted that formal education strongly interacts with non-formal and informal learning. Planetariums provide very attractive and exciting non-formal educational activities. The permanent placement of a museum environment, such as a planetarium, inside a typical school allows us to explore interactions between formal and non formal education, to experiment new didactic processes using activity theory, to track comparisons and differences between our case and the usual situation that the planetarium is placed out-of-school. The first conclusions on integrating non-formal learning activities of astronomy in a classroom reveal a large increase of interest among students for the science of Astronomy and a significant improvement of their astronomical knowledge.

Introduction

An astronomy education program for pre-primary and primary school students is described in this paper, which is part of a wider research in science education that aims to bridge the gap between formal and non-formal learning, and to develop new science curriculum within museum education introducing methodological tools from the field of Cultural Historical Activity Theory (CHAT). Modern science education is strongly related to museum education and involves various formal and non-formal processes (Hein, 1995, Pedretti, 2007, Pedretti & Soren 2007, Kokkotas & Plakitsi, 2005). Science Museum visitors are being motivated to actively participate to hands on activities (Gregory, 1989). One of the primary functions of modern museum environments is the role of teacher (Hooper-Greenhill, 1991) and proposed didactic activities differ a lot from the standard school teaching (Cigada, D'Addato, Danise, Folcio, Gorni, 2003). A technological museum innovation of the twentieth century is the planetarium. From «Archimedes' Sfere» in antiquity and the ancestors of modern planetariums in 17th century (King, 1978), we had to wait until 1923 for the first planetarium's projector, the «wonder of Jena». Its impressive effect promoted the continuous development of planetariums technology which create environments that encompass the audience, bringing them into the experience of an audiovisual technology in a way that classroom, book, or computer screen cannot. In setting these goals, planetariums mediate in all three forms of learning:

academic learning; increasingly in the psychomotor area as we offer more interactive experiences; in the social-emotional learning, as we encourage cooperative enjoyment of the sky (Monsignori Fossi, Righini, 1993).

During the last decades planetariums have been transformed in three-dimensional digital space theatres, but also portable inflatable planetariums have been created. They are mobile and suitable for performances and demonstrations in schools, applying astronomical activities of non-formal learning within the school environment. Such a modern inflatable planetarium was used for our educational program, that aimed to push forward the usual formal education system to a more interactive and self-exploratory model. Mainly, our research was tended to induce planetarium presentations far away from a passive show, and transform them into meaningful learning situations. Finally, we traced paths for further connection between formal and non-formal learning environments, and we also experimented to design non formal activities using CHAT.

Rationale

The astronomy education program, conducted during the 2008-2009 school year in Oikonomou Private School of the city of Ioannina, is part of the Greek actions for International Year of Astronomy 2009. An inflatable planetarium, placed permanently in a classroom of the school, is the central pedagogical «tool» of the educational activity. As a stable planetarium does not exist in the city of Ioannina, the inflatable planetarium is used as a fixed installation with the intention to integrate elements of non-formal learning in a school environment. Accordingly, we experimented with different learning approaches. The planetarium has prompted us to develop applications of «interactive experience model» according to Falk and Dierking (1992). In addition, we focused on activities of «discovering learning» following the didactic approach of Freeman (1989) that includes: i) guided discovery, ii) resolution of the problematic, iii) student action. Furthermore, the innovation of our research is the use of CHAT in order to analyze activities. We also adapted CHAT to design science educational activities (Barab, Barnett, Yamagata-Lynch, Squire, Keating, 1999). Both Vygotsky (1978) and Bruner (1996) stressed the importance of the role of culture in education and argue that the main scope of teaching, which is to introduce children to the skills and methodologies, can be achieved through active learning and cooperation. We applied activity theory, which recognizes the social dimension of teaching and learning, as a designing tool to promote the social involvement and the active participation of students, using the “ideal-typical sequence of learning actions” of Engeström (1999). Therefore, we used qualitative researching methods as video studies and interviewing.

Methods

The research was a case study which focuses on small video-studies. We collected our data by interviews, video-recordings and e-settings among children, teachers and parents. Indirect results were related to trace some dimensions of the relationship between CHAT and action research; a recent discussion started by the *Mind, Culture and Activity* journal, as well as the *Cultural Studies on Science Education* journal.

The innovative program involved 35 kindergarten and 150 primary pupils. The educational activities were carried out twice a month. The sample was divided to groups of max 25 pupils of the same age. The planetarium has a seating capacity of 35 people. It's composed of a Starlab Standard projector, a cylinder of Greek mythology and a starfield cylinder. The planets, the moon phases and 3000 stars are projected on the dome and an audiovisual system was permanently mounted for direct projection of astronomical photos, videos and powerpoint presentations.

Description of the educational programme

Educational scenario

The educational scenario for students from 9 to 12 years old covered an extended range of astronomical issues: definition and differences among planets, stars and satellites, astronomical orientation and identification of

North Star, celestial movement, seasonal position and constellations movement, morphology of solar system's celestial bodies, space exploration.

The scenario for kindergartens and pupils in first grades was enriched with native American and Greek astronomical myths and references to Greek mythological constellations, as myths facilitate the transition from the social environment in the world of knowledge through familiar symbols.

Interactive educational activities

The didactic activities were also related to other areas of the school, such as computer lab, gym and garden's open space. In this way the program was fully integrated, including not only planetarium performances, but also other innovative interactive didactic approaches; such as constructions of simple astronomical instruments, experiments with everyday materials, researches on web, drama and theatrical techniques. All these creative activities promoted interaction, encouraged sensations and emotions, and provoked exploration, discovery, collaborative learning and interdisciplinary approach to knowledge.

Astroparty

The educational program was completed with a very pleasant surprise for the pupils because of the organization of an astroparty, in combination with all-night stay at school. Pupils initially presented to their parents an exhibition of astronomy paintings and an astronomical musical and dance performance. Then they participated in educational activities, such as research of astronomical objects using astronomical maps and observation of the night sky using telescopes. Special planetarium shows for the parents have been also organized. Pupils from 9 to 12 years old equipped with sleeping bags and great enthusiasm, decided to overnight at school and they turned at home il day after.

Methodological keys

Students' ideas

Particular emphasis was placed on assessing students' ideas. Children bring to the acquisition task some initial knowledge about the physical world which appears to be based on interpretations of everyday experience (Vosniadou, Brewer, 1994). The educational programme focused in a particular way on the correction of misconceptions and the right understanding of scientific concepts.

Active involvement

The active involvement of pupils was one of the main objectives of the educational process. Systematic non-passive attitude of students through observation, participation in workshops, encouragement of discussion were selected as key elements for the enrichment of the implemented activities.

Encouragement of motivation

Learning is decisively influenced by students motivation. Planetarium is an excellent teaching tool for development incentives. The “magical” atmosphere of the night sky, the mythological representations of the constellations on the dome, moon phases and the Milky Way contributed in a decisive way to the development of children's interest in the science of astronomy, to the continued development of curiosity for astronomical phenomena, and the highly participatory behavior.

Use of myth and drama

The use of educational tools such as myth and drama, contribute to a learning environment that creates a fertile ground for the conception of scientific phenomena able to enrich the experiences of students. By exploiting the diversity and the creation of mystery, pupils are emotionally involved and they mobilize intensively to investigate cognitive areas associated with abstruse concepts and phenomena. Using the myth students explore new ideas and construct new knowledge shapes using considerations that create cognitive bridges from the familiar to the unknown world of knowledge in question (Pietrie, 1986). Myth and drama promote the imagination that enriches the educational processes and contributes to manipulate a wide arena mentally.

Social interaction

Learning is primarily a social activity. Interaction and participation in school's social life are fundamental keys through which learning occurs. According to psychologist Lev Vygotsky (1978), children learn internalizing activities, habits, vocabulary and ideas of members of the community in which they grow. For this reason, the creation of a productive and cooperative atmosphere is an essential part of learning at school. Social partnership can improve students performance, providing that interaction contribute positively to learning.

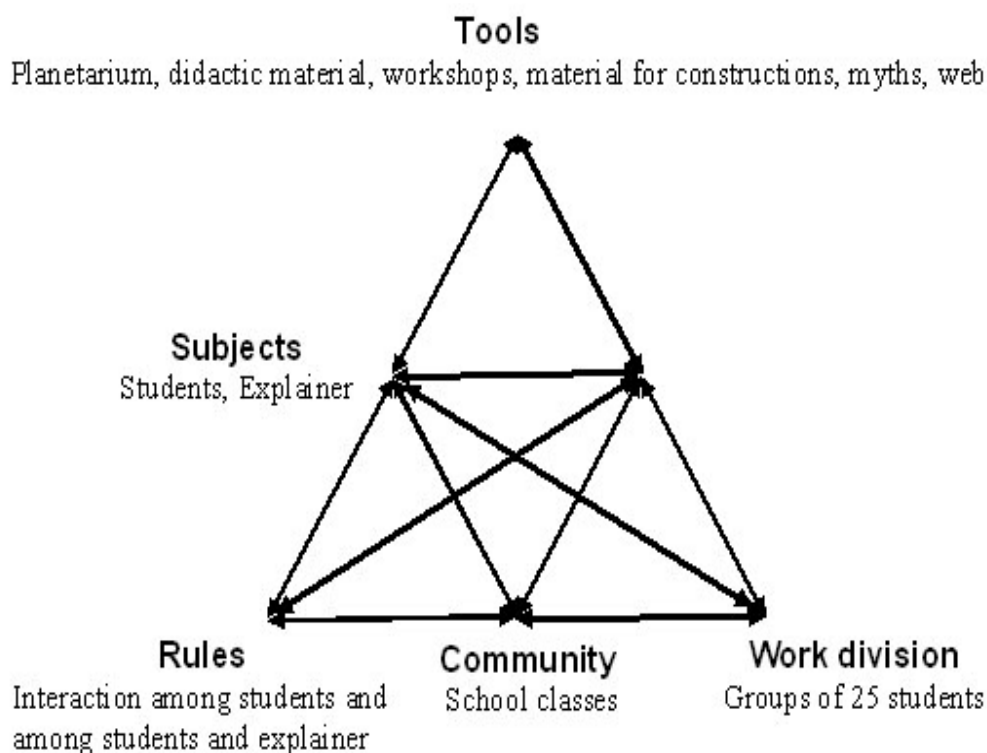


Figure 1. Engestrom's triangle applied to our educational programme of Astronomy

We applied Activity Theory using Engestrom's triangle (see Fig. 1) and promoting social involvement through continuous interaction and encouraging discussion among students and among students and the explainer. We also encouraged the participation in cooperative activities, such as discovery of astronomical issues on the web by groups of students, organization of astronomical exhibitions of paintings from groups of 25 students. Collaboration in groups promoted a lot the quality of the work.

Results

<p>Motivation</p> <ul style="list-style-type: none"> • 97% of students of all ages was impressed by the night sky.
<p>Emotional effects</p> <ul style="list-style-type: none"> • 67% of all ages students had the impression that the planetarium was a spaceship and they were travelling in space. • By the end of the scholar year, 89% of all classes students said that the planetarium was still equally amazed at them as during the first performances. Only 11% of them expressed the opinion that the planetarium is still very nice but not so much impressive as during the first times.
<p>Social interaction</p> <ul style="list-style-type: none"> • Non formal activities and CHAT contributed to make children more social, creative and active.
<p>Cognitive effects - Reconstruction of previous knowledge</p> <ul style="list-style-type: none"> • Students of preschool, of 1st and 2nd primary became familiar with the use of the terms “star”, “planet” and “satellite” and with the designs of basic constellations. • 63% of students from 9 to 12 years old were able by the end of the project to identify inside the planetarium the major constellations such as Great Bear and Orion. • 72% of them were also able to understand the basic differences between stars and planets and between planets and satellites

Comparison between:

<i>Stable planetariums</i>	<i>Inflatable planetariums located in formal environment</i>
The stable planetariums, and especially the digital ones, impress more than the inflatables because of their multiple technical effects.	However, our inflatable planetarium still remains as popular as the first time among children and it inflames their imagination.
The scholar visit in a planetarium is a very special event for students. On the contrary, the repeatability of planetarium performances at school could reduce the impressive effect.	However, the classroom where our inflatable planetarium is located is still considered as a «magic» area that pupils would like to visit more frequently than the planned visits.
The limited number of school visits to planetariums due to practical reasons, usually causes: -the passive participations of students -the difficulty for the museum educator to introduce a significant number of topics and to interact strong enough with the class.	The increased number of didactic activities of a planetarium fixed in a formal environment: -reinforces the educational astronomical scenario and enriches it a lot in terms of issues -permits to prepare and to post-elaborate in classroom the non formal activities obtaining significant evaluating results.

Conclusions and Implications

A permanently placed planetarium in a school becomes inevitably, over time, part of the school equipment and of the school formal proceedings. However, the enrichment of the educational program with parallel hands-on activities and astronomical interactive workshops, using a variety of didactic approaches, helps to keep students' interest in high levels. Moreover, the long duration educational programs offer substantial and specialized pedagogical results.

The experimentation of new methodological processes using activity theory in non-formal pedagogical actions demonstrates the importance of cultural-historical activity theory (CHAT) in science education, and contributes to a school open to the society and to lifelong learning, pushing us to create innovative educational activities in non-formal and museum education. The integration of non formal activities in a formal environment promotes the active participation, the group work, the interaction and the emotional involvement of students and it becomes nowadays a necessity that could oxygen the sterile school reality and motivate students to meaningful learning.

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ATOM SURPRISE: USING SCIENCE DRAMA TO TEACH BASIC SCIENCE

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Abstract

As interest in science drops, the science education community has to seek new ways of teaching and engaging children. One such strategy, which has so far received little research attention, is the use of theatre. This approach can be seen as part of the humanistic science education movement. This study, which is part of a larger project, focuses on the learning outcomes of a science play for elementary school children on the topic of matter, using a combination of quantitative and qualitative research tools. Results from two studies are presented. In both children's knowledge on the subject of matter increased after viewing the play, with younger children gaining more conceptual understanding compared with their older peers. In one of the studies girls increased their knowledge more than boys did. The viewers were more likely to hold the misconception that molecules can be seen after watching the play, probably because a model of a molecule is presented during the show. Results from this and similar studies could help science educators and creators of science plays utilize science drama more effectively and increase children's engagement and motivation to study science.

Introduction

As the interest of young people in science drops and less students are choosing to specialize in science (Osborne, Simon, & Collins, 2003) "more attempts at innovative curricula and ways of organising the teaching of science that address the issue of low student motivation are required" (Osborne & Dillon, 2008, p. 8). The remediation should take place at an early age, since students' interest and attitudes toward science usually form by the age of 14 (Osborne & Dillon, 2008). One possible teaching strategy which addresses the above but has so far received little research attention is the use of theatre in science teaching. Not only can drama and theatre increase children's motivation and interest in science, but drama can also aid in the cognitive learning process (Ødegaard, 2003).

The use of drama in science education can be seen as part of the humanistic science education movement (Yoon, 2006). Its aim is to provide science education with a more human, socially relevant and appealing face; one that presents science as a human and social endeavour with all its strengths and weaknesses, in the hope of attracting more students to science and facilitating the learning of science (Stinner, 1995). Within the humanistic science education movement calls are found to approach science through strategies such as narrative and stories, affect and drama.

In this article we adopt the definitions offered by Schonmann (Schonmann, 1995) for drama and theatre in the educational context. Theatre is a process of interaction with an audience (such as in a traditional play). Drama in the educational context refers to the actual experience of the learner using theatrical tools (i.e. active participation of the learner).

Rationale

The practical advantages of using drama in the classroom have been examined by several science educators. Drama and theatre facilitate the learning process by emotionally involving the observers and participants (Begoray & Stinner, 2005; McSharry & Jones, 2000), and resulting in active learning (Braund, 1999). It is a student-centred inquiry-based strategy (Alrutz, 2004), which may motivate those pupils whose special talents are not usually employed in science lessons (Braund, 1999). Theatre may also increase audience engagement in science by stirring emotions on scientific issues, keeping the audiences interested with narrative, offering a cultural and historical context for scientific information and supporting the image of scientists as humans (Halpern, in press). On a more philosophical level, drama bridges the traditional gap between science and the humanities and creates a more holistic learning experience (Begoray & Stinner, 2005). A further advantage of drama in science education is one that addresses a remark by Osborne and Dillon (Osborne & Dillon, 2008): the "contemporary obsession [of youth] with celebrity". By using drama, science may for a while be brought on stage and become a 'celebrity'.

Although there are several reports on the use of drama in the classroom (e.g. Hadzigeorgiou, 2006; Kofoed, 2006; Metcalfe, Abbott, Bray, Exley, & Wisnia, 1984) little research is available on the use of theatre in science education. This study is a part of a larger project that aims to understand and characterize the learning process of watching an educational science play as well as to derive research-based design principles for the production of educational plays in general and educational science plays in particular. In this report we will present results that describe the contribution of an educational science play to the knowledge and attitudes of viewers, and how this contribution changes with age and gender. It will also describe how different theatrical elements are perceived by the viewers.

Methods

In order to study the change in knowledge and attitudes of elementary school children after watching a science play, a one-group pretest-posttest design was applied. Mix methodology of pre-post questionnaire and in-depth interviews was used. This report presents the results from the questionnaires only. Further evidence from the interviews will be available in due course.

The play

Atom Surprise is a forty minute, two-actor play portraying several basic concepts of matter (mass, volume, atoms, molecules and the three states of matter). In the story a boy and a girl enter science class for the first time (see figure 1). Through interactions with the teacher, a magic adventure and a treasure hunt the two characters (and consequently the audience) become familiarized with the world of matter. In addition there is a short account of Dalton and the formulation of the atomic theory. At a certain stage in the adventure the characters must 'enter' different materials and find out what they are. The play climaxes with a TV style game show. In addition to the science themes, there is also a repetitive prosocial theme throughout the play of children's (high and low) self-esteem with respect to science, school and other students. One of the researchers is an actor in the play.



Figure 1. The two characters in *Atom Surprise*.

The sample

The study was conducted in two school settings in Israel.

Study I – public (state) school

The play was presented to the entire student body of an average achievement elementary school from a non-deprived socio-economic background as an enrichment activity. The study group was a convenience sample, consisting of male and female students from 2nd (n=55 pre and n=53 post) and 4th (n=64 pre and n=46 post) grades, chosen based on the school's and teachers' cooperation. The questionnaires were anonymous, therefore changes were observed at the group average and not on the individual level. According to the school's science coordinator most information concerning matter was obtained from the school's enrichment programs.

Study II – a private school

The play was presented to the entire student body of a high achievement private elementary school as an enrichment activity. The study group consisted of male and female students in six intact classes from each grade level (grades 1-6; total n=145) Questionnaires were anonymous, and pretest-posttest pairing was done using a student serial number.

In both schools some 70% of the students claimed to like science. In the first school 72% of the pupils claimed to have no acquaintance with the topic of matter, whilst in the second school it was 55%.

Assessment tools

For quantitative assessment of the knowledge change, written questionnaires were designed to address four main issues: (1) knowledge on the topic of matter; (2) misconceptions on the subject of matter; (3) children's general attitudes towards science; (4) children's attitudes and feelings towards the play after having watched it. Matching questions from categories (1) and (2) appeared both in the pre and post questionnaires. The questionnaire was validated using an expert validity procedure and tested on a small control group (n=20) that did not watch the play. No significant change in average scores was found for the control group. For the first graders a shorter version of the questionnaire was developed which was read in full by one of the researchers. Other young children were helped with the reading individually. In-depth semi-structured interviews were conducted in order to gain a richer understanding of the learning process, following procedures used by Nakhleh & Samarapungavan (1999) in their

investigation of children's beliefs on matter which included sample materials. Video recording of the play were also used to remind and to initiate discussion.

Statistical analysis

Knowledge gains were analyzed using three approaches: (I) An overall score of correct answers was assigned to each student. Significance was tested using independent samples (in study I) and dependent samples (in study II) t-test. (II) Significant differences in the average scores among boys and girls were tested using independent samples t-test. (III) In order to find the effect of the intervention on specific concepts a chi-squared test was performed on each of the questions separately (on the number of correct, incorrect and "do not know" answers pre and post intervention).

Results

In order to compare children's pre- and post-play knowledge, average scores were calculated. Overall the viewers demonstrated a significant increase in scores from 55 to 64 (a 16% increase) in the first study and from 63 to 75 (a 19% increase) in the second study. All scores are presented on a 0-100 scale.

Age

Figures 1 and 2 show the variation of test scores with age in each school. As might be expected, the older the children the greater the knowledge they had both before and after the play. In both schools, all age groups showed an increase in score after watching the play, yet the knowledge gain of the younger students was greater than that of the older ones. (In the public school 2nd graders showed a 32% increase compared to a 13% increase for the 4th graders. In the private school the increase of 1st-4th graders was 35%-28%, much greater than the gain of 5th-6th graders (4%).

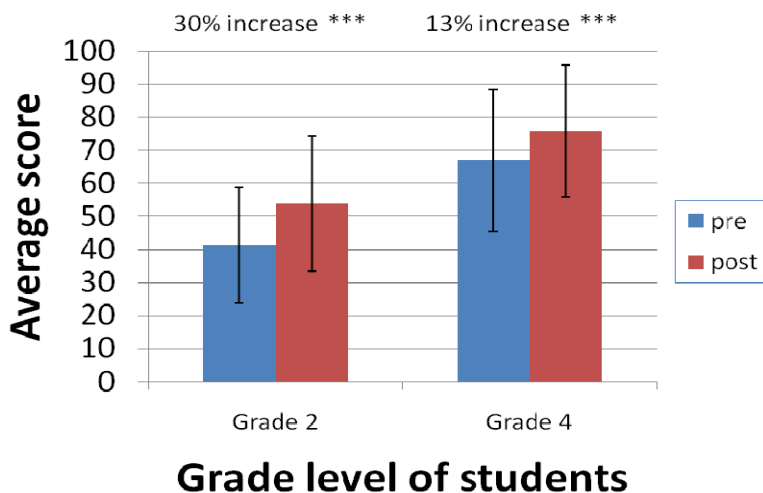


Figure 2. Pre and post test scores in the two age groups in the public school. Significance was tested using independent samples t-test and is marked: * - $p < 0.001$. Error bars show the standard deviation .**

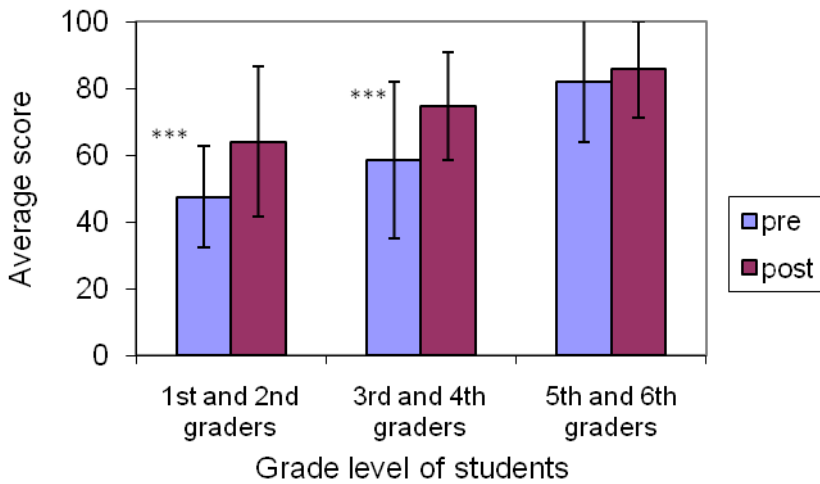


Figure 3. Pre and post test scores in three age groups in the private school. Significant increase in score was tested using paired sample t-test and is marked: *** - $p < 0.001$. Error bars show the standard deviation.

Gender.

In the public school boys' average scores were higher than the girls' before the play. Yet after having watched the play, girls scores were slightly higher than the boys' scores (figure 4).

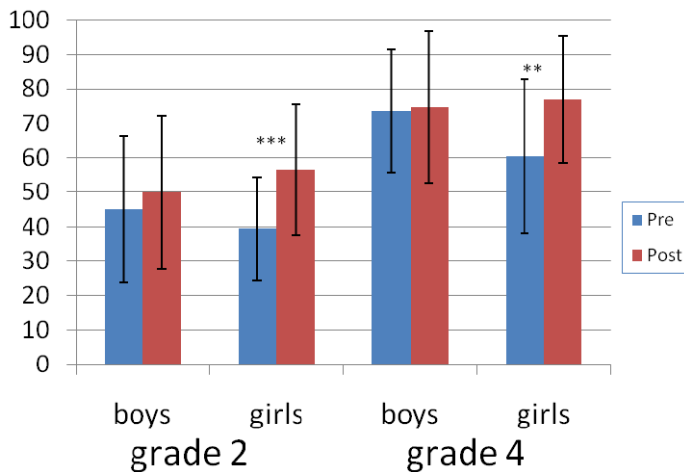


Figure 4. Pre and post test scores in Study I showing a gender difference. Significance calculated using independent samples t-test and is marked: ** - $p < 0.01$; *** - $p < 0.001$. Error bars show the standard deviation.

This result was not repeated in the private school as can be seen in figure 5. Boys' average content knowledge scores were higher both before and after the play, a trend found at all grade levels. Both girls and boys added an average of 12 points to their scores: the average boys' score improved from 66 pre test to 78 post test (17% change, $p < 0.001$), while the average girls' score improved from 60 in the pretest to 72 in the post test (21% change, $p < 0.001$).

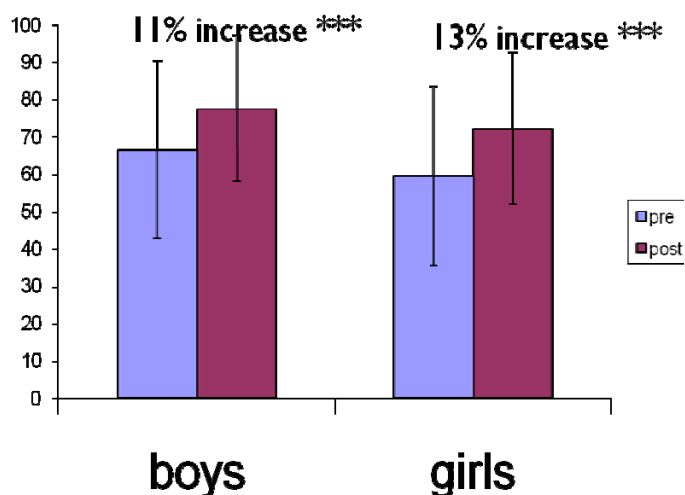


Figure 5. Pre and post test scores in study II by gender. Significance was tested using paired sample t-test and is marked *** - $p < 0.001$. Error bars show the standard deviation.

Science concepts

The items that showed the highest increase in correct answers are shown in table 2. These were Water/air is matter; An elephant / a fly have big mass; The smallest particle constituting matter; A molecule is made of atoms. It seems that the play was successful in introducing the concepts of matter, atoms and molecules.

Whilst there was a significant increase in the elephant/fly question, no such change in a question was found when children had to choose the object with the greater mass or volume out of two illustrated options. The comparative volume question had a very high rate of correct answers before the play (96%), so there was no much room for improvement. It seems that the play did not succeed in changing the way children applied the concept of mass as there was no significant increase in the mass comparison question.

Table 1 – percentage of correct answers for statement that showed most pre-post difference. Significance was tested using χ^2 test. * - $p < 0.05$, *** - $p < 0.001$.

Statement being tested	Percentage of correct answers					
	Public school		Private school			
	Pre	Post		Pre	Post	
Water/air is matter ¹	55%	68%		59%	85%	***
An elephant / a fly have big mass ¹	44%	64%	***	60%	73%	*
The smallest particle constituting matter ²	33%	53%	***	47%	73%	***
A molecule is made of atoms ¹	36%	73%	***	60%	88%	***

¹ - questions with three options: true/false/do not know; ² - multiple choice question with four options.

A model of molecule is used during the play. It was the researchers' concern that such a brief encounter with the model with no further explanation of the difference between a real molecule and a model would cause confusion. A question was added to both the pre and post questionnaires as to whether molecules can be seen with no microscope without a microscope. Whilst there was virtually no change in the number of correct answers in the public school (56% to 55%) and only a slight increase in the private school (70% to 75%) between the pre and the post questionnaire, there was an increase in incorrect answers (12% to 36% in the public school and 12% to 20% in private school). The number of children who replied that they did not know the answer decreased significantly (from 32% to 9% in the public school and from 19% to 5% in the private school). It seems that many children did not know what a molecule was before the play. After they play they did, yet many developed the misconception that

molecules may be seen with the naked eye. Whilst the play does stress this fact verbally several times, it seems that this had less impact than seeing the model.

Children's views on the narrative content

As part of the formative assessment children from the second study (the private school) were asked to state their most and least favourite aspects of the play. Answers were classified into six emerging categories: the children's feeling towards the play, scenes mentioned, characters mentioned, theatrical effects, storyline and scientific/knowledge content. Many children did not mention particular features that they liked, but simply mentioned that they liked or disliked the entire play. From the articulated replies the following trends were seen:

Scenes

The children most liked the TV style quiz show. This is the climax of the play, it provides the most tension and the audience can partially participate in this scene. In the second most mentioned scene the characters enter the materials (this was both liked and disliked). The rest of the comments were spread approximately evenly across the scenes, apart from the historical story of Dalton which was not mentioned (this was also seen in the interviews). In the Dalton scene the actors portray a short account of Dalton's life and his formulation of the atomic theory. The actors do not speak and there is a recorded sound track that tells the story. This might be one reason why the scene is not remembered.

Characters

Most positive replies were received for the boy in the play and the most negative about the girl. The boy is somewhat of an antihero; he lacks self-confidence yet wins the big prize at the end. The girl is more of an uptight perfectionist, and gets irritated quickly. Many comments stated that they did not like the girl's bragging. It must be noted that children do not always distinguish between what they feel and what they think about the character. When asked to articulate in the interviews many did make the distinction that although they didn't like the character, they realized it adds flavour and humour to the show.

Theatrical elements

Many children noted that they liked/disliked the particular artistic style of the play (all artifacts are exaggeratedly big and there is a lot of use of physical theatre) indicating that they were sensitive to the artistic style. Some children, especially the older ones (grades 5 and 6) thought that there were too few characters on stage and that it was too childish.

There were very few comments concerning the science/learning content in the play.

When asked whether they felt they learnt in the play 29% felt that they learnt a lot, 51% felt that they learnt a bit and 20% felt that they didn't learn anything in the play. No significant difference was found between the gender and age groups. When asked to mention something they learned in the play, the terms atoms and molecules were the most prevalent.

It seems that while the children proclaim to have learnt from the play, they were more concerned and involved with the artistic/narrative aspects of the play.

Children's self-reflection on the learning process

When asked what they felt about the learning process in the second Study, 29% of the children felt they learnt a lot, 51% felt they had learnt a little and 20% felt that they did not learn from the play. When asked to elaborate on what they learnt during the play, the terms atoms and molecules prevailed.

Conclusions and Implications

This study focused on the effectiveness of a play in teaching science content. It seems that the play was effective in teaching the concepts of mass, atoms and molecules, as was seen both by the knowledge part of questionnaires as well as the children's self-reporting questions. It was less effective in teaching how to apply these concepts in comparing different objects. It seems that the younger children learnt more from the play than did the older children. This could be due to the older children possessing higher initial knowledge or that they might find the play childish and aimed at a younger crowd. Further investigation by interviews will shed more light on the issue.

In both studies girls started off with a lower initial average questionnaire score. Whilst in the private school (Study II) this gap was also apparent after the intervention, in the public school (Study I) this gap was basically eliminated after watching the play. The difference between the two studies may be explained by the different types of schools in which the studies were preformed. The public school (in Study I) is a regular public school in which there is no special stress on science education. The private school (in Study II) is a high-achievement private school in which the children receive a lot of science enrichment. In addition many of the children's parents are from a scientific/technological background.

The results found in the public school have been mirrored in several other studies. Rockman et al. (1996) studied the popular "Bill Nye the Science Guy" television series in the United States by observing 8-10 year old children (total n=1350) who were exposed to a number of episodes of the series over a period of several months. They discovered that while girls do not begin with the same knowledge-base as boys, the series served to narrow this gap since the girls gained more science knowledge than the boys did. Tveita (1999, 2000) found that girls learned much more from a unit using drama to teach electricity than from traditional methods and achieved a level equal to boys (despite previous researches showing that boys normally do better than girls in the topic; Jovanovic, Solano-Flores & Shavelson, 1994 in Tveita, 2000). Interestingly a later study (Klepaker, Almendingen, & Tveita, 2007) showed Norwegian girls to be more enthusiastic to learn science through role-play and drama than the Norwegian boys (this was the only learning method amongst 18 other options to show such a gender difference).

In order to infer on the general effectiveness of theatre in science education, investigations of other plays, interviews with artists and scientists who have created science plays, interviews with children and teachers, and the use other forms of drama in science education are currently being conducted. This study has shed some light on the field of science teaching using theatre, yet it was conducted under certain limitation. The study focused only on immediate post play results. A delayed posttest should be administered later this year. In addition in the public school we were not able to pair questionnaires, limiting the certainty of the results.

It is hoped that the results from this study and future studies could help science educators and creators of science plays utilize the tool of theatre more effectively and increase children's enjoyment and motivation to study.

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ANALYZING INTERACTION OF DIFFERENT CONTEXTS IN A SCIENCE CENTRE: THE CASE OF SOLAR ASTRONOMY COURSES

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Abstract

UNESCO declared 2009 as the International Year of Astronomy, when several outreach educational activities are promoted all over the world aiming at stimulating interest in astronomy and science, especially among young people. Science centres as part of informal education offer unique opportunities to motivate students towards science by contextualizing teaching contents. Astronomy is a fascinating science subject due to its contents, to possible interdisciplinary approaches and by the fact it attracts students towards contemporary science. The present paper describes results obtained in a Brazilian science center following a short solar astronomy courses for middle and high school students in a room totally dedicated to the Sun, the Solar Room, designed with simple and inexpensive equipment. Solar physics topics as sun dynamics, chemical composition and stellar evolution were discussed with practical and enquiry-based activities such as observing sunspots, prominences and solar spectrum. In order to analyze collected data, we used the Contextual Model of Learning by Falk and Dierking as framework. Learning in a science centre is a personal process, highly dependent on previous experiences comprising different contexts: personal, social-cultural and physical. This process encompasses several sources, experiences and information that are responsible for knowledge building. The present paper investigates how these different contexts interacted during the solar astronomy courses.

Introduction

UNESCO declared 2009 as the International Year of Astronomy (IYA2009), when several outreach educational activities will be promoted all over the world aiming at stimulating interest in astronomy and science, especially among young people. IYA2009 is a global celebration of astronomy and its contributions to society and culture and marks the 400th anniversary of the first use of an astronomical telescope.

Astronomy is a fascinating science subject due to its contents; it enables interdisciplinary approaches and attracts students towards contemporary science. Notwithstanding, literature on astronomy education is mainly devoted to teacher and student conceptions of Earth, seasons, Solar System and moon phases. At schools, astronomy is seldom taught using practical activities, such as observation of planets, Sun, stars and their movements, since covered topics are usually limited to textbook information. In addition, astrophysical contents such as the nature of the Sun, stars, galaxies and other heavenly bodies are hardly explored.

Such topics should be addressed because they attract students' attention towards contemporary science, leading to a closer understanding of the origins of the Universe and mankind. One of the reasons these contents are not taught in schools is that most teachers did not have the opportunity to study them in their preparatory courses. Teaching astronomy only in school setting is not enough to motivate students (Braund & Reiss 2006). An alternative

for coping with these problems is to teach astronomy topics in informal spaces such as science centres, astronomical observatories, and planetariums.

These informal educational settings offer unique opportunities to a contextualized learning and foster inquiry-based activities since students can have access to authentic scientific tools and practices (Aroca et. al. 2008). Thus, the main role of museums and science centres is to motivate students towards science, since they offer an attractive environment allowing students a direct contact with instruments and scientific practices (Falk 2001).

The present paper discusses results obtained in short-term solar astronomy courses for middle and high school students. The courses were held in a Brazilian science center in a recent launched room totally dedicated to the Sun, the Solar Room, designed with simple and inexpensive equipment. Due to the complex character of the learning process in informal setting, we adopted the Contextual Model of Learning (Falk & Dierking 2000) as evaluating tool for the solar physics courses.

The Contextual Model of Learning

The Contextual Model of Learning is an important tool to investigate learning in science museums, since it considers the interaction of different contexts that influence in the process. Thus, it is important to investigate how different contexts interact in order to learn solar physics concepts at the Observatory, since learning in this setting is a personal process highly dependent on previous experiences, occurring in a socio-cultural context that involves many sources, experiences and information that together are responsible for knowledge building.

Recent research in learning in science centres has shown that it is not possible to adopt the same evaluation strategies used in formal education (Falk & Storksdieck 2005). One of the reasons is that informal education comprises many variables that depend on context and change from one visitor (including students, teachers and citizens) to another. Such variables are part of the Contextual Model of Learning: Personal, Physical and Sociocultural contexts. All these contexts are overlayed by the factor time, since learning is a gradual process with many sources that demands time.

The Personal context involves motivation and expectations; prior knowledge, interests and beliefs; choices and control. Within the Sociocultural context are group mediation; facilitated mediation by others and cultural background and upbringing. The Physical context embraces orientation; architecture and large-scale environments; design; reinforcing events and experiences outside the science center.

Methodology

In order to promote solar physics outreach activities a solar room was built at the Astronomical Observatory of Scientific and Cultural Dissemination Centre of University of Sao Paulo. The room is equipped with spectroscope, solar H- α filter, light bulbs, solar charts, and spectral charts. Several educational activities take place in this room, among them two short-term solar physics courses for volunteer students held in 2006 and 2007 discussed in this paper. The *Observing the Sun* course lasted 8 hours and was attended by middle school students (age 11 to 14). It was focused in presenting the Sun as a dynamic star by observing sunspots, prominences and discussing their nature. While the *Solar Physics* course lasted 14 hours, was attended by high school students (age 15 to 18). Its main objectives were to foster the comprehension of the key role played by spectroscopy in astrophysics, to contextualize contents with practical activities, and to allow interdisciplinary approaches including modern physics and chemistry in physics teaching (Aroca et. al. 2008). In order to avoid hazards, safety procedures during solar observation were highlighted.

The adopted methodology during the short courses strongly relied on a constructivist approach, with observational and guided inquiring activities; for example, students were inquired about solar nature, sunspots and

prominences before and after telescopic observations. This teaching strategy allowed personal solar conceptions to be confronted by solar observations and group discussions.

The data collection consisted in videotaped classes and interviews, pre and post written questionnaires. In the beginning of the courses, before conducting practical activities, written questionnaires were applied in order to highlight students' alternative conceptions about the Sun. At the end of the courses, another written questionnaire was applied containing more elaborate questions in order to evaluate students learning and if alternative conceptions continued or were substituted by knowledge more closely related to the accepted by the scientific community.

Interviews were held at the end of the course, consisting of three questions related to students alternative conceptions presented at the beginning of the course and to course activities. The interviews were individual, semi-structured, which means that no specific routine was followed, questions were re-formulated or eliminated according to students answers (Aroca, 2008).

Solar representations, nature of sunspots and prominences (ages 11 to 14)

Research in astronomy education has shown that students present confusing ideas about the Sun, Moon and other heavenly bodies (Colombo Júnior et. al. 2009; Bailey 2008; Zirbel 2004;). Before the course *Observing the Sun* students conceived the Sun as bright and hot sphere or disc and used terms as magma and volcanoes in order to explain the composition of the solar surface and solar prominences. Students tended to interpret the Sun, planets and stars as being very near each other (Bisch, 1998), as shown in the bellow fifth grade student representation (Figure 1). This kind of misrepresentation is commonly found in textbooks which pictures stars as small points without clarifying that they are background objects. Regarding solar surface, students conceived it as similar to lunar surface (Figure 2).

A seventh grade student, expected to observe the Sun with explosions larger than the solar diameter, as can be seen in his drawing on Figure 3. This conception is very interesting since most astronomy books and internet material explain that the Sun has an external layer, the solar corona, which extends through the Solar System. What the student did not know is that the corona would not be observed in the course, but only some details of another external solar layer, the chromosphere (visible through a Hydrogen-alpha filter). Other features that can be seen in the solar representation of this student are small squares or circles inside the solar disk. These were referred by him and his colleagues as holes in the solar surface, and were probably representations of sunspots.

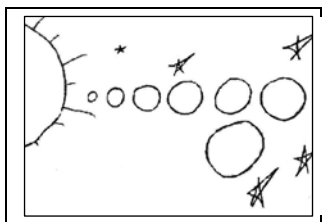


Figure 1. Sun representation of a fifth grade student.



Figure 2. What an eighth grade student expected to see on the Sun through a telescope, translation of what the student wrote in Portuguese: “full of craters, with some layers around it”

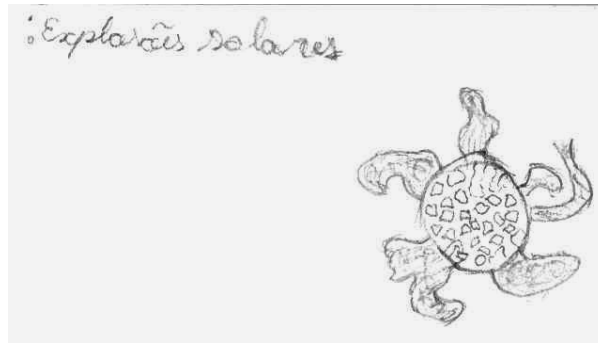


Figure 3. Sun representation of an eighth grade student with “solar explosions”.

These students probably saw solar images in the media presenting dark spots, and their alternative explanation for them would be holes created because of high solar temperature. Some students used geology knowledge as a starting point, for example, lava and magma learned in science class to try to explain solar nature, thus considering previous knowledge and experiences from the Personal context.

During the course, the Sun was observed using a projection method which enables the study of solar dynamics by sunspot observations (Figure 4) along several days and with the aid of a hydrogen-alpha filter by a direct observing method which permits prominence visualization (Figure 5).

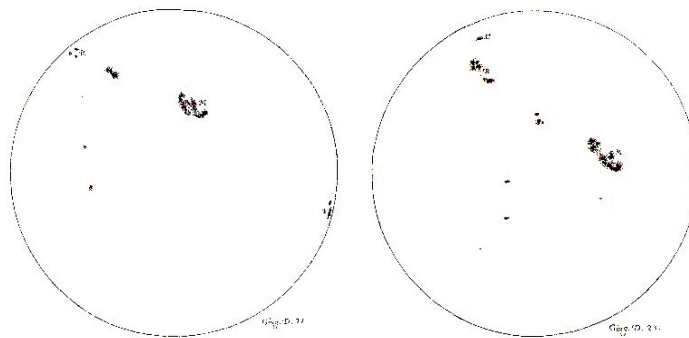


Figure 4. Sketches made by Galileo in 1610 showing sunspots. Figure from: *Istoria e Dimostrazioni Intorno Alle Macchie Solari e Loro Accidenti* Rome de Galileo Galilei.

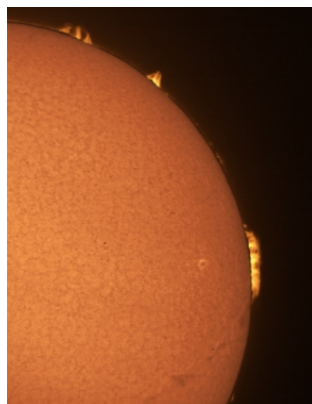


Figure 5. Copyright 2005, Ginger Mayfield – Prominences in the solar limb.

In the 2006 edition, students realized that sunspots could not be craters since their size, shape and position continually change along the days. Students' conceptions on solar prominences also changed because they observed modifications in shape, brightness and color in a matter of minutes indicating that they are not analogous to volcanoes' lava. In the 2007 edition, only solar prominences were observed because there were no visible sunspots on the solar disk. In order to explain these observations, seventh and eighth grade students developed a model. According to it, the Sun exhibited no sunspots because bubbles produced by hot lava had not cooled yet and darkened enough to produce sunspots. From this model it is clear that students conceived sunspots as being craters and prominences as lava expelled by volcanoes.

All three contexts of the Contextual Model of Learning were responsible for building students solar model. The Personal context accounted for previous notions of geology, simultaneously the Sociocultural context was also important, since knowledge was built during dialogues mediated by the group and teacher. Finally, the Physical context, made solar observations possible, and enabled the solar model to be tested by systematic observations.

Nature of visible solar spectrum (ages 15-18)

In the pre written questionnaire students were asked about what they expected to observe in the solar spectrum during the *Solar Physics* course. Some students answered they would observe details in the solar surface like craters while others answered they would observe the colors of the rainbow. Only one mentioned spectral lines. A curious comment was given by student *We*, that it would be possible to observe X rays, ultraviolet and Gama rays, the student expected to observe the complete electromagnetic spectrum during the course. This answer points to the fact that the student did not know that Earth's atmosphere intercepts most of the solar radiation and that our eyes are unable to see them.

Students were also questioned if the Sun has chemical elements, and if so, how do we know it, since it is not possible to extract a piece of material from it in order to analyze in laboratory. All students stated the Sun is composed of chemical elements. Some students reasoned that chemical elements are detected in the Sun because of the solar rays. Students were probably referring to solar light when they mentioned light rays. Another answer was given by student *V* that knowledge of solar chemical composition arises from satellite observations of the solar surface. The student believed the Sun has a homogeneous composition, meaning that the solar nucleus would have the same composition as the solar surface, so according to the student it would be possible to determine the solar interior composition only by studying the solar surface.

Several students wrote the Sun is rich in hydrogen and helium, but were not able to explain why. A very confusing answer was given by student *We*, that Sun light contains several materials like helium and magma because it is responsible for photosynthesis. This naïve conception showed the student probably believed the Sun would provide chemical elements by radiating light that would then be absorbed by plants during photosynthesis.

Another student wrote that the reason we know there are chemical elements in the Sun is because of nuclear fusion and fission. His answer indicates he was aware that chemical elements are synthesized in stars, but did not know the process responsible for chemical element production in the Sun. Two students mentioned there are elements like iron in the Sun, and this is known because of spectroscopy.

The students that associated the solar spectrum with rainbow colors, probably learned that from textbooks, that is, due to their previous knowledge and experiences of the Personal context, when looking at pictures of solar light rays being decomposed by a prism which is responsible for the same phenomena that produces a rainbow, refraction. Students who assumed it would be possible to observe the solar composition, were probably influenced by previous interests of the Personal context obtained when reading astronomy books, visits to the Observatory, watching documentaries on the theme, or even browsing through homepages in the internet. Student *We* answered that it would be possible to observe the complete electromagnetic spectrum, this misconception probably arises

from theoretical knowledge gained from physics textbooks about the electromagnetic spectrum, without discussing the practical implications of observing it, being the result of previous knowledge from the Personal context.

In order to understand the nature of spectral lines, students handled the major parts of a spectroscope and learned how prisms and diffraction gratings produce light refraction, reflection, scattering and diffraction. Students were requested to observe lamp spectra, draw and verbally describe to classmates and teacher while looking through diffraction gratings. After recognizing the existence of different patterns of bright lines in each kind of lamp, they were asked to identify the lamps by comparing their observations with a spectral chart (Figure 6). The next step was to observe the solar spectrum which was projected on a white paper (Figure 7). When students observed the solar spectrum they realized the presence of dark lines. The differences between the lamp spectra and solar spectrum were discussed and some solar spectral lines were identified (Aroca et. al. 2008).

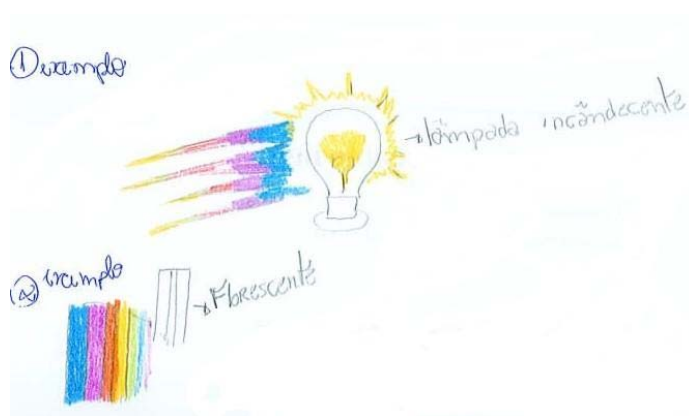


Figure 6. Ninth grade student sketch of incadesentent and florescent lamp spectra.

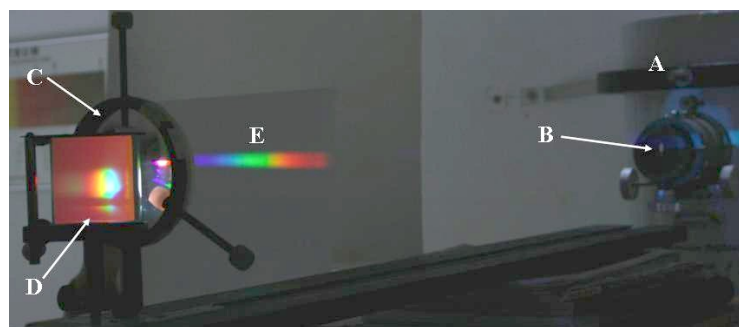


Figure 7. Image of the spectroscope used in the *Solar Physics* course. A is the telescope, B is the slit, C is the collimator lens, D is the diffraction grating and E is the projected solar spectrum.

Since students had already studied in the *Solar Physics* course the Sun's structure (nucleus and atmosphere) they were encouraged to apply Kirchoff's laws in order to comprehend the reasons why dark lines are present in the solar spectrum. Due to the teacher mediation, students were able to realize that the Sun core acts as a blackbody, which emits a continuous spectrum. The solar atmosphere is in a much lower temperature, thus it absorbs some of the core radiation producing the observed dark lines in the solar spectrum (Aroca, et. al., 2008).

The *Solar Physics* course also addressed stellar evolution and chemical elements synthesis. Students learned that the Sun only synthesizes elements as heavy as Helium. This made them inquire about how other heavy element lines are found in the solar spectrum and if the Sun had somehow incorporated those elements from elsewhere in the universe. This discussion made students comprehend that stars are gigantic furnaces of chemical elements.

Analyzing post written questionnaires and interviews showed that students understood that stars are composed by the same elements as Earth, and that spectroscopy is a powerful tool to determine stellar composition (Aroca et. al. 2008).

Conceptions such as solar rays or that solar radiation is a chemical element did not appear in students' answers to the final written questionnaire concerning the existence of chemical elements in the Sun. This probably occurred because students observed and identified some spectral lines, concluding that they are the same in Earth, and because of discussions that were held on the synthesis of chemical elements in stars.

Student *We* wrote in the final questionnaire that the Sun has many elements, such as, helium and carbon dioxide that were detected by spectroscopy. The student confused chemical element with molecule, writing that carbon dioxide is an element, instead of a molecule. This student probably maintained his initial conception that solar radiation would be responsible for providing chemical elements to plants during photosynthesis, since he mentioned carbon dioxide, the plants main respiration source. The other students answered that solar composition is known because of spectroscopy, but only two students informed detail of how this is done.

In the final written questionnaire students were inquired about what are the solar and lamp spectral lines, and why the solar lines are dark and the lamp spectral lines are bright. Most students answered that the spectral lines are chemical elements, and that bright lines in lamp spectra are emission lines and dark lines in the solar spectrum are absorption lines. Student *We* wrote that lamp and solar spectra are "*colors that mean the presence of some chemical element and dark lines are also chemical elements.*" This answers shows the student understood that spectral lines are an indication of chemical elements in solar and lamp spectra.

Students answers concerning solar chemical composition point to serious problem in formal teaching, since students learn names and words, such as, helium, light, magma, photosynthesis, but are not able to address them meaning. Thus, informal education settings have an important role in meaning making, since they allow science school content to be contextualized.

Final comments

Learning in a science centre is a personal process, highly dependent on previous experiences comprising different contexts: Personal, Sociocultural and Physical (Falk & Dierking 2000). This process encompasses several sources, experiences and information that together are responsible for knowledge building. The present paper investigates how these different contexts interacted during the solar astronomy courses.

The Contextual Model of Learning considers the influence of three different contexts. In the solar astronomy courses the Personal context was an important factor to determine students initial conceptions, since they were influenced by previous experiences, for example, notice the Sun burns the skin, and conclude that it must be observed with extreme care through a telescope. Students' motivation and previous interests of the Personal context were also responsible for attaining and concluding the courses.

The Physical context and Socio-cultural context were determinant during and after practical activities because of the adopted methodology. The Physical context was especially important during solar and lamp spectra observations, since it was possible to contextualize taught knowledge on the Sun and solar physics aspects. The Sociocultural context allowed teaching to be more practical and inquiry-based than just using classroom and textbooks. Students felt stimulated and challenged during activities that privileged the use of dialogues, experiments and observing the Sun through different methods. Discussions of students' main ideas were also a source of content learning stimulus by provoking reflections and new inquiries.

Results point that elementary students conceive the Sun as constituted by fire; sunspots as holes and prominences as blaze of fire or magma. Seventh and eighth graders developed a model to explain the sunspots

absence and appearance related to prominences using general concepts about the Earth. These naïve conceptions changed after students: observed the Sun through telescopes; were questioned about their initial conceptions and because of teacher mediation. They noticed that sunspots couldn't be holes caused by solar heat, since every new observation showed they grow, shrink and shift position. Another fact is that prominences could not be composed of magma. During observations students followed the emergence and changes in sunspots and prominences. Thus, students began to see the Sun as a dynamic star, interesting to be observed and studied and that affects our lives in many aspects.

High-school students' conceptions concerning the solar spectrum were quite variable. Some students had no idea about its nature, and stated they would observe details on the solar surface, others related the solar spectrum to colors of the rainbow, presenting some knowledge on the subject. There were also cases in which a student expected to observe the whole electromagnetic spectrum during the course and finally some students knew they would observe the solar chemical composition.

Some students returned to the Observatory to participate in other activities. For these students the course attracted them to astronomy and other branches of science. Out of school contexts stimulated students towards promoting new connections with science, thinking more about it and its implications to society, and the appreciation that learning has wider boundaries than schooling.

Astronomical contents taught in an interdisciplinary inquiry-based form challenges staff members of institutions such as the Observatory. The need for at least two types of activities in science centers must be highlighted. The first type is activities that superficially address themes, such as expositions, brief lectures and short observations. These activities have as main objective to motivate the visitor towards science. The second type would be to offer brief courses to volunteers, since language, contents and longer activity methodologies can facilitate interdisciplinary and integrating approaches of astronomy with other scientific knowledge, seldom explored in classroom.

Thus, it is vital that teachers deepen their knowledge on astronomy and other disciplines, such as physics and chemistry in order to have competences to propose integrated and interdisciplinary activities as the ones discussed. This can occur when the schools' pedagogical project is constructed collectively with science centers, teachers, schools and students. Only this way, will it be possible to embrace a proposal of science teaching that considers out of school context and that also has strict relations with students' curriculum.

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IMPLEMENTATION OF PHYSICS EDUCATION IN NATURE: FRAMING INFORMAL INSTRUCTION INTO FORMAL SETTING

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Abstract

Within this research, using the data separately gathered as a result of the three year pursuit of the one semester area elective course of prospective physics teachers, a description of the implementations has been aimed at being clarified and thus a comparative analysis has been conducted in order to determine what kind of differences and/or similarities exist. The course integrates indoor and outdoor settings and emphasizes on strong social interaction between participants, displaying the connection between physics and nature and constructing solution methods for ill-structured problems. By means of this course they get a chance of sharing a common life experience in a residential outdoor setting. This experience is also effective in the construction and solution process of ill-structured problems conducted indoors. They encounter ill-structured problems they have never experienced in other courses and in which they have had difficulties in general. In the last stage, the students are encouraged to reach the most optimum solution among alternative solutions by way of qualitative data gathered during the observation of and experience in nature. The studies show that the differences in significant common results are dependent on the differences in implementations through years.

Introduction

People have tried to understand the behavior of the natural world since antiquity. Physics covers a wide range of phenomena in this natural world and it aims to describe them in terms of simpler phenomena. This fact has its effect on science education resulting in a need for the inclusion of enriched learning environments including nature in the field. However the willingness to take on the responsibility to teach outside the classroom is undervalued. In fact, it may be viewed as disruptive and unproductive (The Association for Science Education, 2007) though informal learning environments are ideal settings for learners to practice skills necessary for scientific inquiry. Moreover experience and observation are key to the scientific inquiry process. Experiential learning may be defined as learning based on personal experiences or direct observation (Bourdeau, 2004).

Experiential education that has been traditionally equated with outdoor education (Bourdeau, 2004) is a recent trend in the area of science education. Consistently the new education standards that are applied in different countries also exhibit this trend. The new standards which are being applied by the Training and Development Agency for Schools (TDA) from September 2007 (TDA, 2007) require that Qualified Teacher Status (QTS) should enable teachers to demonstrate that they can: 'Establish a purposeful and safe learning environment conducive to learning and identify opportunities for learners to learn in out of school contexts'. These standards are used as a further stimulus to strengthen the profile of outdoor science teaching in Initial Teacher Education (ITS). Training and development should include testing scientific hypotheses out of doors, developing field skills of measurement, observation, testing and recording, observation of areas of the outdoor environment using both qualitative or quantitative means, demonstrating and contrasting how the scientific enquiry process, how science works – can be applied in a variety of situations, including some in which variables may be difficult to control or manage, illustration of how scientific concepts studied in the classroom and laboratory also operate in outside settings, addressing outdoor scientific problems and issues, illustrating how several strands of science are often required to interpret

environmental issues, experience of addressing scientific issues in novel circumstances (The Association for Science Education 2007).

The following quotes also illustrate the value of personal experience in learning:

“Amid all uncertainties there is one permanent frame of reference: namely, the organic connection between education and personal experience” (Dewey, 1998).

“For experiential education to be effective it has to be undertaken as part of a learning framework (Huckle and Sterling, 1996).

Recently researchers in the area of science education have included real-life problems that are known to be ill-structured into their studies to include experience as a basis. We encounter with ill-structured problems in daily life and there is not sufficient information to solve them. Thus it is problematic for students to solve real-life problems since they are different from and more difficult than book-type problems.

Campbell, Lubben and Dlamini (2000) found the percentage of responses demonstrating the use of science low particularly for students who have been taught through a context based approach, and thus they suggested that bringing ‘everyday situations’ into ‘school science’ does not readily enable students to bring ‘school science’ into ‘everyday situations’. Similarly, Fortus (2005) suggests providing students with an experience in which they apply their knowledge in real world contexts.

In addition to many of its advantages, framing informal instruction into a formal setting is a difficult process, especially if nature is involved as an educational setting. Then an important resource for physics education still seems relatively unexplored: physics activities in ‘nature’ (Popov, 2003) where children make meaning from their direct experiences (O’Brien and Murray, 2007). Gürel et al. (2007) argue that although it is obvious how important the outside school experience is for their profession, very few teachers attempt to make use of it, however the ‘applied knowledge’ they need to establish in their science classes is a connection between science and daily life. Krupa (2002) states that the potential for educational opportunities in an outdoor classroom is limitless. He worked on field trips in biology education and according to him one of the perceived drawbacks of field experience in outdoors is that what is available varies greatly from location to location and effective field trips require exercises that are spawned from the experiences of the instructor. Moreover the nature of activities is completely dependent on the geographical location and the facilities.

This is also consistent with the holistic approach Orion (2007) insists on to be adopted in science curricula. He states that the holistic approach is not disciplinary-centred but multidisciplinary including earth and environmental sciences and not classroom-based but it integrates multi learning environments including indoors and outdoors.

On the other hand, through the outdoor facet of this study it is investigated whether the outcomes of the experiences overlap with Social Constructivism Theory of Vygotsky. According to this theory knowledge is social in nature and is constructed through a process of collaboration, interaction and communication among learners in social settings (Vygotsky, 1978).

The need for an enriched learning environment, particularly including nature, is handled through the integrated setting of this study which includes indoor and outdoor settings in the same process to support one another with the purpose of incorporating some informal science instruction into a physics course.

Purpose

In this study, we aimed at clarifying the findings concerning the effects of the variability in outdoor instruction based on the characteristics of people and environment. For this purpose, the similarities and differences between the instruction periods in three consecutive years, from 2006 to 2008, were studied, so the factors that affect the results of the implementations were revealed.

Research questions

The research questions that are given below are constructed depending on people and environment factors:

- What similarities constituted the core of the course?
- What differences exist in instruction depending on the characteristics of people included in the outdoor part of the study?
- What differences exist in instruction depending on the properties of nature as residential camping areas included in the study?

Methods

This is a comparative analysis of the three cases which include the conduction of Area Elective course given at Physics Education Department at Marmara University in three consecutive years, from 2006 to 2008. The two researchers discussed the similarities and differences for reliability and agreed upon them. There were different people in outdoor part of this learning environment, except for the researchers each year, and outdoor settings or the properties of those settings all changed.

In comparative analysis, depending on Pickvance (2001), the variation finding comparison was basically used. However universalizing comparison for common properties and individualizing comparison for specific situations in each case were also used. The analysis of simple and complex causal structures that lead to the results are not included in this study. This analysis is left for further research. There might be a set of correlations that describe the groups studied in each case for some specific situations. In this study we only present those situations that should be analyzed to decide about possible correlations.

The participants were prospective physics teachers, civil defence volunteers and experts as collaborators. The first author as the instructor of the course, since 2006 and the second author, a PhD student since 2007, have taken part in the study as researchers.

Data Collection

Data were collected through field notes. All the data were coded according to the conditions that appeared, basing on environment and people, and the similarities and differences were revealed. In this study the researchers manifest some conspicuous outcomes of the whole process selecting from field notes according to research questions. The course was planned regarding the needs and characteristics of students (prospective physics teachers) viewing them from the widest perspective. Researchers met weekly for the evaluation of the course and some changes in the program were made if required. They were also in contact with collaborators regularly. The course was also evaluated as a whole at the end of the term and it was planned each year regarding the overall evaluation of the previous year. The researchers noted all these evaluations and the process regularly. The course was planned regarding the needs and characteristics of students (prospective physics teachers) viewing them from the widest perspective.

The integrating course

In this course an approach was adopted to incorporate outdoor settings as an integral element of Area Elective course included in the programme for physics teacher education. The term outdoor is used as a large context including nature as a residential camping, field trips and activities in campus garden as complementary experiences of the residential camps. The course is designed to provide transition from one setting to another. The experience of a residential camp plays a key role in the transition from outdoor learning setting to indoor. In this way outdoor setting is not overused but the advantages of using both indoor and outdoor settings are combined. In the heart of the course is experience and observation in outdoor settings.

The course is open to change and renovation and it is this feature that attracts the researchers. The frame of the course is stable but there is flexibility in the problems and the object of learning is taken from nature. The course has been integrating indoor and outdoor settings interactively and the problems taken from outdoor settings have been brought into the class in ill-structured form. The solution process of these problems is not included in this study. Gürel and Doğan (2009) investigated the ill structured problem related to campfire in detail. Table 1 describes the similarities of three cases in terms of people and environment.

Results

There are some research questions of this research related to the solution process of ill-structured problems, students' learning styles, attitude and motivation being investigated in some master's and PhD theses. They are not included in this study. Significant common results are only emphasized depending on the differences and similarities in three cases. The differences and/or similarities in the conduction of the course are given case by case in Table 1-6. Differences or similarities in results for each case are given in Table 7-10.

Table 1. Similarities of Three Cases

Ill-structured problems were brought into the class with a holistic approach.
No specifications concerning physics and the context were given in the beginning, but the context was established through the activities conducted in the process.
The purpose of the course was the same.
The experience was real and new.
Students participated in outdoor activities including camps with their classmates having to perform all the tasks in collaboration with others.
The residential camping was used as a direct experience.
The course started in the context of nature with a search of a problem for the same ill-structured problem: " <i>How could you construct the habitat in nature?</i> "
The activities conducted in camps each year based on the starting problem were generally the same as core activities, such as building a campfire, navigation during the day and at night, pitching a tent etc. modifying due to the conditions year by year, but the ones that were investigated in detail might change depending on the research questions of master's and PhD theses.
The activities conducted in camps were planned in collaboration with civil defence volunteers.
Students were not experienced in and confident about solving ill-structured problems.
Participation in the camps was optional for the students in the class.
Photographs and videotapes were taken and stories were written by participating students.
Their photographs, videotapes and narratives were used in ill-structured problems and students' outdoor experiences were used in the solutions of these problems.
Participating students shared their outdoor experiences and photographs taken during outdoor activities, field trips, garden activities and camps with their non-participating friends.
Some students volunteered to help with organization of certain aspects of the course.
Some of the questions prepared by participating students were also used in the final exam.

Table 2. Differences Among Three Cases

The organizers and the experts of outdoor activities
Prospective physics teachers participating in the research
The weather and general conditions of the campsites
The other people who did not take place in the study but were present in the surrounding area
The collaborating experts
The organizers and the experts of outdoor activities

Table 3. Experience of the Participants

2006	2007	2008
Neither students nor the instructor had any residential outdoor experience.	With increasing residential outdoor experience of the instructor, the researcher and volunteers, the content of the course, the depth and number of the problems expanded. Because the problems were formed in accordance with students' own experience, they were modified depending on the conditions each year.	
The case of 2006 was the preparation and experience gaining period for the subsequent theses.	The cases of 2007 and 2008 included some research questions of the master's and PhD theses conducted within the course. Research studies in 2007 and 2008 were also conducted as the pilot study of the doctoral thesis of the second author under the supervision of the first author.	

Table 4. Collaboration with volunteers

2006	2007	2008
There was a direct collaboration with a trained civil defence volunteer from Civil Defence Directorate. This collaboration led to the foundation of Marmara University Civil Defence Club.	The collaborating civil defence volunteer died unexpectedly and this affected the conduction of the course and all organizations. Some other civil defence volunteers from Civil Defence Directorate collaborated only for the camp. A core group of the members of the club started to have the same training as a civil defence volunteer.	The core group of the members of Marmara University Civil Defence Club completed all the necessary trainings, thus there was no need for collaboration with other civil defence volunteers for the organization of outdoor activities.

Table 5. Differences or Similarities Between Two of the Cases

2006	2007	2008
Logistics, security and first aid, collecting wood for the campfire and cleaning the campsite were accomplished by civil defence volunteers or members of the civil defence club throughout the camps.		Students taking the course accomplished all the tasks including logistics, security and first aid, collecting wood for the campfire and cleaning the campsite throughout the camps.
For the first camp in 2006 and for the only camp in 2007, the groups went to the same place for camping.		For the first camp the group went to a new place for camping.

Table 10. The results in terms of experience

2006	2007 & 2008
Problems were based on the activities in which the collaborating civil defence volunteers were experienced.	With the increase in support by experts and the experience of the researchers, variability in problems and a depth in solutions were provided. New problems related to new activities and field trips were added.

Conclusions and Implications

Similarities and Differences

In Table 1 summarizing the similarities in three years it can be seen that a consistent framework was constituted from the beginning and it continues.

In Table 2 it is presented that outdoor instruction led to a flexibility in the formation of problems and this flexibility had a developing characteristic for some topics. However the problems were formed around a core experience. With the same core experience, problems had variations year by year depending on human factor and environmental factors; different characteristics of different people in different conditions. Nevertheless the program generated new problems depending on the properties of the group and the experiences they gained within the course. The recursive problems related to the basic requirements of a residential camp such as pitching a tent, building a campfire and navigation at night led to the development of related conceptual knowledge of the instructor, researcher and students.

Limitations

- The course was given during the students' senior year at the university when they had a great anxiety about getting a job. They also had to take an exam called KPSS, which is necessary to get a job in the government. To be able to work as a physics teacher at a state school, prospective physics teachers have to get a high score in this exam.
- They were busy working at weekends or attending private teaching institutions for KPSS.
- The university and students had a limited budget.
- There was a need for support from external institutions like civil defence directorates in the beginning.
- One semester was not long enough for students to have both such a new experience and to solve ill-structured problems and thus the first semester was also included with a prerequisite course.

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THE MOTIVATIONAL FEATURES OF AN INDUSTRY SITE VISIT

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Abstract

In this research it is examined how students with different motivation orientations and external observers experienced and evaluated an industry site visit sequence, which took place in a materials science context, and how the sequence was re-designed according to the evaluations. The design process, which had several iterative cycles, followed the principles of Design-Based Research (DBR). Students' (N=15) motivational orientations were examined by Academic Motivation Questionnaire (AMQ) based on the Self-Determination Theory (SDT). According to their answers, students were grouped by K-means cluster analysis into three categories: 'amotivation', 'controlled motivation' and 'autonomous motivation'. One representative of each cluster was interviewed. The interview was a semi-structured interview, and the analysis followed principles of theory-driven content analysis. Questions and analysis categories were based on SDT and interest theories. The most significant motivation and interest supporting features of the sequence for the students were the possibility to study in an authentic context and features that actuated the feeling related valence of students' interest. Based on the analysis of the interviews, activities that support students feeling of autonomy and social relatedness in the direction of the aims of the sequence will be emphasised when re-designing the sequence.

Introduction

The investigation of students' attitudes towards studying science has been a distinguished concern of science education researchers for the last 30–40 years (Osborne, Simon & Collins, 2003). A problem revealed in the studies of this field is a decline in the interest of young people in pursuing scientific careers. Many pupils feel alienated from a discipline that has increasing significance in contemporary life, both at the personal and societal level. This problem has been identified widely, but an effective way of solving it is still absent. Osborne, Simon & Collins (2003) argue that the point of view of the research on motivation should be taken into account when searching for possible solutions to the problem.

In this research an industry site visit teaching-learning sequence, which includes several motivation and interest supporting features in order to facilitate students' motivation to study science, was designed by a Design-Based Research approach, and then implemented and evaluated. This research is a part of the *Materials Science (MS) Project* funded by the European Union. The focus in this paper is to examine the motivational features of the visits.

The motivational features of site visits are examined in the light of the self-determination theory (SDT) (Deci and Ryan, 1985, 2004, 2008). According to SDT motivated behaviour or motivation style may be *autonomous (self-determined)* or *controlled* and they involve different reasons for behaving. External and introjected regulations are forms of controlled motivation, whereas identified and integrated regulations and intrinsic regulation are forms of autonomous motivation. Autonomous motivation involves behaving with a full sense of volition, whereas controlled motivation involves engaging in an activity because it leads to some separate consequences. Autonomous motivation exists when people experience satisfaction of their basic psychological needs. According to Deci and Ryan (2002) the basic psychological needs are a need for autonomy, a need for competence, and a need for social

relatedness (need for belonging to a group). Amotivation means that a person has no motivation at all to conduct a task, and it results from a person not valuing a behaviour or outcome.

Not only intrinsic motivation, but also well-internalised forms of extrinsic motivation (integrated and identified regulations), are associated with more positive human experience and performance, and they have positive effects on the quality of learning (Deci & Ryan, 2008; Guay, Ratelle & Chanal, 2008). Although students primarily produce their motivation, it can be enhanced and learned. Practices supporting students' feeling of autonomy, social relatedness and feeling of competency, and fostering interest result in both greater persistence and better quality learning (Deci & Ryan, 2008). A site visit which has been planned in co-operation between a teacher and students is an example of a learning task, which could enhance autonomous motivation because students have the opportunity to feel responsible for a competent performance.

Interest has close relationships to process-oriented motivational concepts such as intrinsic motivation or the experience of self-determination. Interest is a content-specific concept, and it encompasses feeling and value related valences. Learning motivation based on interest tends to have many positive effects on the process and the results of learning (Krapp, 2007). Interest is approached from two major points of view: It can be personal or situational, being aroused by something in the learning environment. Situational interest is spontaneous and exists only for a limited period of time (Krapp, 2007). If the situational interest is maintained long enough, usually with external support, it may develop into personal interest which is topic specific, persists over time, develops slowly and tends to have long-lasting effects on a person's knowledge and values (Krapp, 2007; Hidi & Renninger, 2006).

Teachers have the opportunity to have an influence on students to develop academic interest towards a certain topic. Situational interest can be sparked by environmental features (Hidi, 2006). One possibility to awaken and deepen interest in science is to take the students outside of the school, and study science in a real-life context, for example at an industrial site (Langsford, 2002). Furthermore, out-of-school visits help students to improve scientific and technological literacy in society, and inform young people of the career opportunities in industry (Braund & Reiss, 2004).

The research questions were:

1. How do students, teachers and external observers experience and evaluate the industrial site visit teaching-learning sequence, especially features intended to promote interest and motivation towards science and science related careers?
2. How was the module re-designed and developed further according to the evaluations as a motivating way of teaching science outside the classroom?

Methods

As a methodological framework, the design-based research (DBR) approach is used in this study. Design research engages researchers in the direct improvement of educational practice (Edelson, 2002). The theoretical products of design experiments have the potential to be utilised because they are filtered in advance, and they also speak directly to the types of problems that practitioners address in the course of their work (Cobb, 2003). Juuti and Lavonen (2006) summarise that DBR emphasises the following three aspects: 1) A design process is essentially iterative starting from the recognition of the need to change praxis. As conjectures are generated and perhaps refuted, new conjectures are developed and subjected to test. The result is an iterative design process featuring cycles of invention and revision. The intended outcome of the iterative process is an explanatory framework that specifies expectations that become the focus of investigation during the next cycle of inquiry (Cobb, 2003); 2) DBR generates a widely usable artifact, like learning activity or environment which is directly applicable in practice (Edelson, 2002); 3) It provides educational knowledge for more intelligible praxis. In the knowledge acquisition process, the pragmatic viewpoint as a philosophical background for design experiments emphasises the role of a

teacher's reflected actions as well as the researcher's involvement in the authentic teaching and learning settings (Design-Based Research Collective, 2003; Bell, Hoadley & Linn, 2004).

DBR encompasses the combination of theory development, the prescriptions of successful design processes, and the description of successful design solutions. The design process contains four main phases: 1) understanding the users' (in this case teachers') world; 2) theoretical problem analysis and definition of the objectives for a design solution, artifact; 3) design and production of the artifact; and 4) evaluation of the artifact. During the design and production phase, there are typically several cycles: designing of a prototype; evaluation of the prototype in real classroom settings; revising the objectives based on the evaluation; and re-designing. This design-production-evaluation-re-design phase together with the needs assessment can also be called empirical problem analysis (Edelson, 2002). As a final design solution (artifact) of our design process, based on the data collected from the cycles, a student book and a teacher guide will be developed to help teachers in organising industrial site visits in the future.

Designing the Site Visit Teaching-Learning Sequence

The site visits to companies, which utilise modern materials in their products, are designed as the cycles of the design-based research. The intention is to study science, and professions related to it, in a real-life context. There are motivation and interest supporting features included in the site visit procedure. From the SDT and interest point of view, these features can be classified into the following categories: support for feelings of autonomy; support for feelings of competence; support for social relatedness; support for feeling and value related forms of interest; and interesting materials science contents and context. The motivation and interest supporting features can be put into practice for example through student-centered learning tasks which are possible for the students to solve, collaborative planning and learning tasks, surprise-evoking inquiry tasks, and constructive evaluation methods.

The site visit consists of the following phases:

- 1) Advance planning by teacher
- 2) Co-planning with the contact person at the enterprise
- 3) Preparation of the students
- 4) Site visit
- 5) Students' articles
- 6) Evaluation and feedback
- 7) Collecting ideas for the future site visits

For the time of the teaching-learning sequence, students adopt the role of reporter. The students' output is an article about a certain aspect of the company, for example the products or the personnel of the company. Before the site visit students familiarise themselves with the webpage of the company, learn what a reporter does, and how to write an article. Before the visit, students plan the preliminary questions to be sent to the experts of the company. During the site visit students make notes about what they see and hear. They also interview persons who are essential to the topic of their article. After the site visit, students write articles based on their notes and interviews, as they planned beforehand.

Preparing the articles in collaborative groups supports co-operative learning and social relatedness and helps students take responsibility over their own work.

Students familiarise themselves with the materials used in the company and the properties of these materials by inquiry tasks before the site visit. During the visit they learn how the materials that they have studied are applied in a real-life context and what kind of standards the use of the material sets for the material.

Collecting and Analysing the Data from the Students, the External Observers and the Teacher

Students (N=15) answered the *Academic Motivation Questionnaire* (AMQ)¹ before the site visit. The questionnaire was used to show how motivating it is for students to learn science, in general. Students representing different motivational categories were chosen for an interview with the K-means cluster analysis. In our solution we chose three clusters and then interviewed the students (students 7, 9 and 11) who were closest to each cluster centre. The selection criteria were also appropriate from the point of view of qualitative classification of students based on the means of different motivation styles. In this selection solution clusters were labelled amotivation, controlled motivation, and autonomous motivation.

The aim of the interviews was to find out what aroused students' interest during the site visit and what motivated them. The interview was a semi-structured interview. The interview questions dealt with the following: students' feelings of autonomy; social relatedness and competency during the site visit and preparing for it; how students' interest was promoted during the sequence; how interesting the students found the context in which the studying took place; and how interesting the materials science contents were in their opinion. The interviews took from twenty to twenty nine minutes, and they produced between eight to thirteen pages of transcript each.

The data were categorised using the categories from the SDT and interest theories following the principles of theory driven content analysis. An output of the analysis is a chart in which the frequencies of expressions in each category can be seen. Through the analysis of the interviews it is possible to discuss the motivational aspects of the site visit significant for students representing different motivation orientations.

Results

Amotivated student

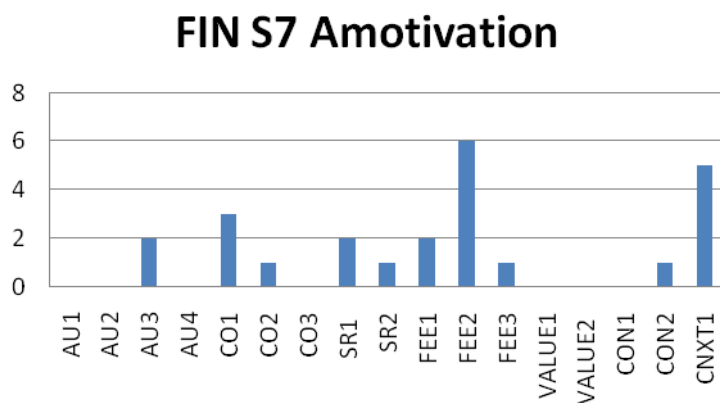


Figure 1. Student 7 Amotivation. The categories from the SDT and interest theory are placed on the x-axis. The frequencies of the student's answers in each category can be seen on the y-axis.

Student number 7 (amotivation) enhanced her motivation through self-competence. She said “*well the interest probably came then and there at Vaisala, like when we had all the answers and all that we needed was that information written down, and then when we defined them at school better and better and when we understood better and better all the time, then the motivation increased then ...*” [CO1]. Also hands-on activities, which promoted her feeling-related valence of interest, were important for her. She said that by “*sending the radiosondes airborne I understood better when I got to try*

¹ AMQ is based on the Academic Self-Regulation Questionnaire (SRQ-A and Academic Motivation Scale (AMA), <http://www.psych.rochester.edu/SDT/measures/intrins.html>

it myself and it was imprinted in my memory in a nice way ...” [FEE3]. Although she went to the visit with a sceptical mind, it turned out that she became very interested in the authentic context, the device presented to her, and how the device worked. As she put it, “well in my opinion the interesting thing was the equipment, they were all different looking and when the man explained at some level the principle of how they work it was interesting ...” [FEE2, CNTX1]. She also experienced social relatedness and closeness with the other student in her pair. She found the learning tasks were easier when done in pairs, and she felt that she and the other student complemented each other. She said that “I always like doing things in a way together with another person, I am not at my best doing things alone somehow, but when we can share opinions and then decide together, even if we both may have different issues and questions, then it somehow goes in easier and we reinforces our learning ...” [SR1, SR2].

Student with controlled motivation

FIN S11 Controlled Motivation

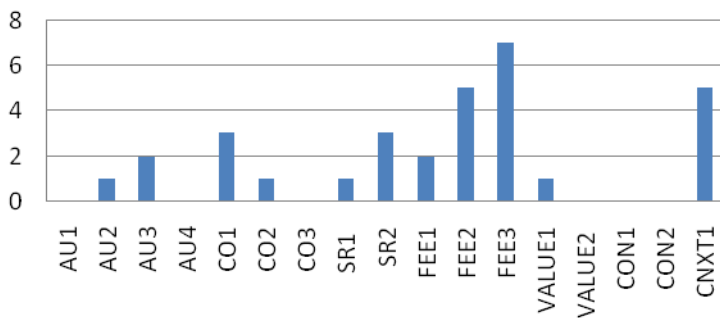


Figure 2. Student 11 Controlled Motivation. The categories from the SDT and interest theory are placed on the x-axis. The frequencies of the student’s answers in each category can be seen on the y-axis.

Student number 11 (controlled motivation) emphasised spending time with her classmates in a nice way, by getting outside of the school. She stated that “...it was nice to go with my friends very early in the morning, go somewhere...then everyone was slightly somehow excited to get somewhere...” [SR2, CNTX1]. She was very interested in the male employee who presented the students the device the company produced. As she put it, “X was really nice, ha ha, I liked him because he was so perky and funny but some of the others, they were may be a bit too severe ...” [CNTX1]. She enjoyed working with her best friend, and she felt she had the possibility to make decisions during the TLS. She said “well yes, in our group we decided how we were about to do it ...” [SR1, SR2, AU1]. She felt writing the report was easy for her because she had listened and learnt during the visit, “the report I managed to do kind of well as I paid attention in the site visit ...” [CO1].

Student with autonomous motivation

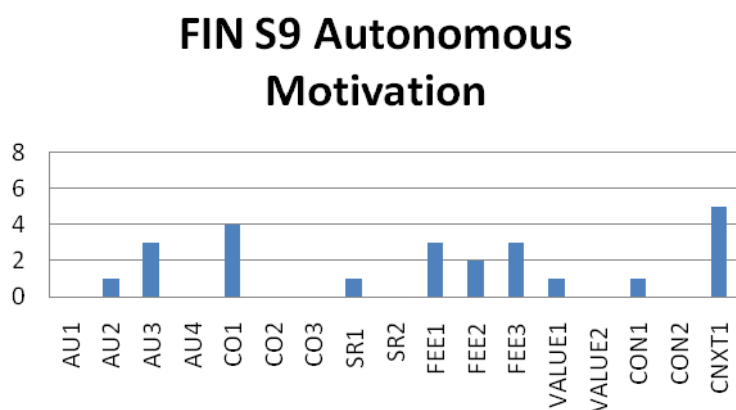


Figure 3. Student 9 Autonomous Motivation. The categories from the SDT and interest theory are placed on the x-axis. The frequencies of the student's answers in each category can be seen on the y-axis.

Student number 9 (autonomous motivation) experienced motivation mainly through enhancing self-competence and feeling of autonomy. As he put it, *“at first we were told what to do but then we planned how we were to do it and what we were to write in it...of course at the beginning when we didn't know anything, well we couldn't do this, but then after the trip when all the things were well placed in my mind and... you managed well like in the beginning, it felt like, like this won't be ok but then after the trip it was a lot more interesting to do... the post visit mind map brought up a lot more issues...”* [CO1, AU1]. He was very interested in the device presented in the visit, saying that *“well, in the first place that is what it was, when they make all kinds of weather equipment... that kind of technology in itself somewhat interests me ...”* [IN1]. He also felt it important to study in an authentic context by saying that *“well probably it wouldn't have been so interesting if we haven't visited the place, if we would just have got familiar with it at school, the visit definitely increased my interest ...”* [CNXT1]. The site visit brought out his value-related valence of interest. He went on by saying that *“yes it changed a bit, for the better, because at first studying chemistry was not so important or I mean now we have been to a company in which, like, it could be seen clearly where one can get by studying chemistry and it kind of increased my motivation ...”* [CNTX2].

Conclusions and Implications

The amotivated student turned out to be quite interested in the topics related to materials science and science and technology in general when these topics were presented to her in an authentic context. Her answers emphasise the meaning of a learning environment with interest promoting features in it.

The student with controlled motivation was very excited about meeting and speaking with the employee of the company who probably turned out to be completely different than she was expecting. This appealing role model may have offered this student a new perspective on technology and careers in this field.

The autonomously motivated student was interested in this subject matter even before going on the visit. The visit made him see the topic from a different point of view, that by studying science he may achieve something that is valuable to him.

In spite of students' motivation orientation, the interviewed students had positive feelings about the site visit. For all interviewed students, support for the feeling of social relatedness was important to them. They enjoyed working in groups and spending time together with their classmates. Also the possibility to get to study in a real world context, outside the school walls, was an important motivation promoting feature for them.

Although all the interviewed students emphasised the significance of working in a group together with friends, the significance of *working together in the context of studying science* did not emerge from the students' answers. The most important thing for the students was to spend time together, with the materials science related task of the group not being so important. Support for the feeling of social relatedness *in the direction of the aims of the teaching-learning sequence* has to be emphasised in the next cycles of re-designing the site visit sequence. The aim is that students will feel it important to study science in a group, not just to join the group. In other words, value-related valence of interest has to be supported alongside the feeling-related valence. Thus the site visit sequence would not just be an enjoyable experience solely constrained to the affective domain students' interest, but it could be a way of helping students to understand the relevance of their own science studies.

In the students' opinion they had only a few opportunities to plan their own studying during the site visit module. The students' feeling of autonomy could be supported by giving them more responsibility in the planning phase, even though they were not dissatisfied with everything being arranged for them. There are many practical things in arranging a site visit, which could be taken care of by the student groups in their own way. In the future, as a consequence of this discussion, the sequence will be re-designed to encompass more autonomy supporting activities, and activities that support students' collaboration in the direction of the aims of the sequence. Also the connection between the sequence and science contents studied at school will be strengthened.

In this paper only the motivational features of the site visit have been examined. Learning, and especially learning materials science related concepts during an industrial site visit, is examined in other papers related to the Materials Science Project.

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A PILOT NATURE EDUCATION IN NATIONAL PARKS PROGRAM: THE CASE OF KÜRE AND ILGAZ MOUNTAIN NATIONAL PARKS

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Abstract

The purpose of this study is to determine opinions of trainees, who participated to ecology based nature education in conservation areas program on the effective national park education (NPE). The education activity was organised by the partnership between Kastamonu City Governorship' Environment and Forestry Directorate and the Scientific and Technological Research Council of Turkey in two terms on July and August 2005 in Kastamonu for graduate students and teacher scouts. 6 trainees (three females and three males) were participated the present study voluntarily. The data were gathered through the interview schedule and were analyzed by using qualitative research procedures. The study indicated that interest is an important element in participation behaviour; practical activities should company theoretical part of NPE; ecotourism or other rural development case studies should be included more in NPE; NPE should target all kinds of people including park inhabitants.

Introduction

The productivity of natural resources has been decreasing rapidly by over consumption and destruction of human activities (Hepcan & Güney, 1996) since industrial revolution (Hepcan & Güney, 1996; Akşit, 2007). Though human beings' use of natural resources for their lives is normal, omitting the sustainability and planning dimensions of this usage forms the main roots of the problems (Hepcan & Güney, 1996). Accordingly the Consumptive World View, which depends on consumption of natural resources to the utmost, has been transformed into the Sustainable World View that implies conservation of these resources against population and consumption (Özbey, as cited in Akşit, 2007). Sustainable Development is defined by the United Nations as the reconstruction that can meet the needs of today's generation at the same time do not risk next generations when fulfilling their needs (World Tourism Organisation, as cited in Akşit, 2007). The principle on the assessment of all natural and cultural resources sustainably covers also the idea of conservation and management of the areas with national and international emphasis and privilege under various categories (Hepcan & Güney, 1996). When we consider the data on the rate of overpopulation and widening of usage areas there will be no place except seas, ice and soil deserts to continue being natural and if we want to leave some natural places we should determine these conservation areas (Kışlalıoğlu & Berkes, as cited in Hepcan & Güney, 1996). Protection Area or Protected Area concepts are a result of this approach (Hepcan & Güney, 1996).

Some of the functions of protected areas can be listed as following (Robertson et al., as cited in Hepcan & Güney, 1996): to preserve continuity and integrity of ecological processes, to conserve biodiversity and ecological stability, psychological and aesthetic benefit, to prepare means for scientific studies and recreational activities, to moderate climatic extremes, and to save historical and cultural diversity.

In order to build a global cooperation on the formation and management of natural areas the International Union for Conservation of Nature and Natural Resources (IUCN) was founded in 1948. IUCN classifies protected areas into six categories (International Union for Conservation of Nature and Natural Resources, as cited in Hepcan & Güney, 1996):

1. Absolute Nature Reserve / Wilderness Area (Absolute nature reserve has extraordinary or typical characteristics and is managed in order to perform scientific studies whereas wilderness area is consisted of untouched or minimally changed areas and aims to protect wildlife here).
2. National Park (It includes the habitats with scientific, educational, recreational and touristic importance, and geomorphologic formations and is managed for preserving ecosystem and recreation as well as scientific and educational purposes).
3. Natural Monument (This place has natural or cultural extra ordinaries and/or aesthetic qualities and is managed to protect these characters).
4. Habitat / Species Management Area (It is a place where nature is protected and some species are survived and is managed to meet the needs of these species and protect their habitats).
5. Sea / Land Landscape Protection Area (These land and sea areas have distinct aesthetic, ecologic and socio-cultural values resulting from the interaction between human and nature and are managed to protect these landscapes and recreation).
6. Managed Resource Area (It is managed for sustainable usage of natural ecosystems for the needs of society and for conserving biodiversity).

National park concept, which constitutes the subject of this study, first came to order in the 19th century in the US, on the other hand in Turkey proposed as an idea in 1940's, and laid legal foundation with a law that became operative in 1956 (Kocataş, as cited in Deniz, Genç, & Demirkaya, 2008). There are four statuses for protected areas in Turkey that were determined by the National Parks Law (Law Number 2873) in 1983 (Milli Parklar Kanunu, as cited in Kaplan, 2003): National Park, Natural Park, Natural Monument, and Nature Protection Area. National parks are important for being a biosphere reserve or for biodiversity (Öztürk, 2002). They are also both affected from the climate changes resulting from global warming and prevent this effect on ecosystems (Öztürk, 2002). Moreover since climate changes will disturb the elements, fertility, and distribution of ecosystems in our country, there is a need for specially reserved and organized parks and reserve areas in north-south and east-west corridors in order to overwhelm these effects (Öztürk, 2002).

Rationale

Undoubtedly, the importance of an environmental education that is organised in national parks undeniable, because as Alım points out environmental education means to develop environmental consciousness in society; to transfer behaviours toward those sensitive to environment, durable and positive, and to preserve natural, historical, cultural, and socio-aesthetic values; to ensure active participation and take a role in problem solving (as cited in Yaşar & Şeremet, 2008). National park education is a part of environmental education and consisted of natural-, historical-, and cultural-based scientific environmental education that takes place in national parks (Yaşar & Şeremet, 2008). With the national park education by introducing the natural, historical, and cultural values of the national parks and their environs participants are tried to observe the qualities of park, to understand its' harmony, colour,

the variety in its' shape and aesthetic, and originality (Yaşar & Şeremet, 2008). From this education it is expected that participants will grow an original style in observing the qualities of the park and in reading it and develop responsibility (Yaşar & Şeremet, 2008). To offer a complete education based on ecology and in this way to develop participants' interdisciplinary thinking skills are one of the main aims of national park education (Ozner, as cited in Yaşar & Şeremet, 2008). The evaluation of national parks, which have many resource values, for the sustainable usage point of view increases the importance of national park education (Yaşar & Şeremet, 2008). With national park education, in order to use national parks for ecotourism scientific background has also being established (Yaşar & Şeremet, 2008). The individual national park consciousnesses that develop related to national park education will eventually transfer into public consciousness (Yaşar & Şeremet, 2008). The characteristics of national parks education that are outlined make an examination of national park education program feasible and help us to develop a more efficient curriculum for the future applications. This study aims to propose an effective national parks education program with the help of people who participated to an environmental education in national parks program.

Methods

In this case study the qualitative methods were used in the research during selecting the participants, and analyzing and reporting the results. 6 trainees from different background were invited to participate to the study in order to get enough in-depth information on effective national park education. After the data was gathered from the participants, the data were transcribed and then analyzed in terms of content.

Participants' Profile

The interviews were conducted with 6 trainees. The trainees were coming from diverse backgrounds. There were 3 females and 3 males. The ages of the group ranged from 24 to 48. Although all participants were university graduates, 2 of them were doing their MSc and 3 of them were PhD students. Of the participants, more than half took a course (four vs. two), less than half were participated to an education program (two vs. four), and the majority had not any project (one vs. five) related to environment before. Additionally the majority of the participants were not a member of any non-governmental organization (NGOs) (one vs. five), and all of them were not regularly subscribed to a scientific journal.

Research Site

National Park of Ilgaz Mountain and Küre Mountains: It is located in Kastamonu and Bartın cities in the west Black Sea part of Turkey and covers 37.000 ha out of 114.000 ha of the planning area, which was announced as National Park in 2000 (Öztürk, 2005). It has a recreational source value for allowing some activities such as tracking, wildlife watching, scene viewing, photographing, rafting, canyoneering, etc. (Öztürk, 2005).

Researchers' Interest

The first three authors have been participated to the several "Environmental Education in National Parks" programs in Turkey. Interviews were conducted by these authors during their participation to both first term (on July 2005 by the second author) and second term (on August 2005 by the first and third author) of the Ecological Based Nature Education Program in Ilgaz Mountain and Küre Mountains National Park, which organized by the Scientific and Technological Research Council of Turkey and Kastamonu City Environmental Directorate took place in Kastamonu.

Data Collection and Analysis

The interviews were conducted to collect data from the participants during the course. The interview schedule included both demographic information and questions parts. Once the interviews with all participants were completed, the digital audio recordings were transcribed and analyzed with the qualitative research procedures. Transcripts were read and notes were taken about important issues from which coding categories were developed. In the content analysis of the data, responses were coded using the categories and broader themes were formed. Results are given with these categories and the related quotations.

Results

1. Aims of attending to the EBNEP

All of the 6 trainees have reported that due to their interest in environment and the course's emphasis on it, they wanted to participate to the program. Moreover 5 of them mentioned that they would like to know about the place (Kastamonu, National Park, and Black Sea Region). As the elements of environment they have highlighted either non-living aspects such as geology or both non-living and living aspects altogether such as flora and human society:

"I am interested in the subjects such as nature, environment, ecology, geology, and natural monuments." (Trainee 1)

"I wanted to participate in order to see geomorphology, flora, and human social aspects of Kastamonu and its' environ." (Trainee 2)

These trainees also emphasized that they expected there were (more) practice, namely field study:

"When I was going my expectation was teaching of the lessons not only theoretically but also practically." (Trainee 3)

They also used visual and visual quality when mentioning practical part due to the place where the course was taking place. One of the participants used the term "observation" instead of "visuality":

"One of the reasons of preference was (it) was devoted to observation, field practice" (Trainee 1)

Moreover she thought that the course was interdisciplinary for trainees and offered them different point of view, as another trainee implied "professional environmental consciousness":

"My aim to participate to the Nature Education Program ... to learn an environmental consciousness from professional view (from trainers) first hand." (Trainee 3)

As a summary, the trainees aimed to see the context of the course and related the sense of sight with taste and experience what makes the national park:

"My aim to participate to the Nature Education Program ... to spend a 10 day with the green together."

2. Place of the EBNEP

The trainees' ideas on the organisation of the EBNEP in a national park were concentrated on the place itself only:

"Taking place in national park for me is appropriate...if there is (a) national park; this (accommodation in the park) should happen in an environmental education related to nature." (Trainee 5)

On the other hand regarding the gains, most of the trainees emphasized the preserved and intact natural and cultural status of the national park along with the teaching-learning activities that consisted mostly of observations, which resulted with cognitive, affective, and psychomotor domain outcomes, such as inspiration and environmental consciousness. For example:

“I was fascinated, liked it very much for the first time. I have learned what a national park means.” (Trainee 4)

“I have seen the area’s cultures in this environment.” (Trainee 5)

“I have seen the events myself, its’ importance, how it is an important factor in preserving environment by examining, seeing, observing. This is very important contribution for me.” (Trainee 6)

“I think it is important to organize in preserved areas and the choice was right. Intact natural areas are the places where more effective results can get.” (Trainee 2)

“I can say that this kind of education for being organized in its place and based on one to one observation in order to be more impressive and lasting in mind was a good choice.” (Trainee 1)

“In this time, when I think that technology has developed in an enormous speed and humanity has become mechanized, and nature, green have not been sensitive properly, I think that National Parks have very important role for preserving natural and cultural resources that our country has. ... In this respect I think that the information gained about national parks is a cornerstone in founding a general environmental consciousness since they helped us to comprehend better the importance of the resources acquired.” (Trainee 3)

The trainees’ views on the alternative places for organization differ. Two trainees thought that the education can be given anywhere, and one of them reflected that it is better to give it in the national park because of it’s facilities. The others felt that if the education was given in another place, it would be ineffective due to the nature of the information, which is theoretical, that allow only didactic teaching method, and monotonous. When the trainees have evaluated the education given here from learning and teaching perspectives, although they found it effective in terms of retention of learning, some reported many pitfalls, such as selection of subjects and trainers, more details given in some lessons.

“I think that the activities in which visual properties are more important that theoretically expositied are more durable. Therefore the education conducted reached its aim.” (Trainee 2)

“Of course there were some insufficiencies: The selection of the subjects to be taught and trainers is important. I think some parts became inadequate and shallow.” (Trainee 1)

“I only think that some lessons since they were detailed more and (in the lessons) more information rather than what could be acquired were given were unfruitful.” (Trainee 3)

3. The congruency between the subject of education and trainees’ aims

According to the trainees the education suited to their aims (2). The trainees expressed that the course helped them to understand the context and how to develop ecotourism projects:

“I think that (it) guided me on finding a response to what I want to do and helped me to clear my ideas. What is the contribution of geology on environmental studies? How it can be used? How does a project be prepared? It was important for being a sample to the projects done.” (Trainee 1)

4. Use of national parks on increasing individuals' consciousness toward environment and gaining positive behaviors

The trainees agree that national parks have a potential to teach public many environmental issues, therefore courses and guided trips should be organized; the courses should also be prepared for the national park habitants on using effectively their resources; initiatives should be taken both by the governmental institutions and NGOs.

"National parks gain importance for making the inhabitants be conscious and using this value." (Trainee 1)

"An effective communication and cooperation between responsible institutions and NGOs should be achieved and required information and coordination should be formed with a participatory approach. Decision-making and planning should be evaluated in this framework" (Trainee 2)

"For this, I think that the advertisement of national parks should be done better. More people should participate to this kind of educations. Guided-tours should be done with the professional guides and its' publicity should be done better" (Trainee 3)

5. The participants and trainers of an environmental education program in national park

The trainees though that an environmental education in national park program should be given to all public regardless of their age, education, and job categories, but educators-teachers-scouts should be given priority due to their profession to educate people; academicians and persons from governmental and NGOs should have also preference:

"We can divide it into two parts: For public, an education to give information and a general view. An education can be given to people who are interested in these subjects professionally or for those who want to improve themselves. I do not know if it is true to limit the participants, but it is better for not deviating from the aim and preparing project to include academicians and from some governmental organizations. There are two target groups one is public for increasing consciousness." (Trainee 1)

"For example to teachers, in particular this should be given with the (ministry of) national education channel. Because you are an academician, (an academician) reaches 10 people, 100 people, but a teacher reaches 300 people. Therefore especially people, specifically teachers should be a prior in this job, and the leaders of environmental organizations that attend to these activities should be got conscious. For example in [place name] there is no NGO but some people that work for this job, work one by one, and not organized. What can be done? For example two-three people from [place name] are gathered, brought. From different places of Turkey these people can be taught on organization method. Anyway they want. May I be clear? Therefore this should be generalized. I think this stand in a particular level and it is not public." (Trainee 4)

All trainees considered that the education should be given by the experts who work on universities, and NGOs.

6. Ideas on the aims, objectives and acquisitions of an environmental education program in national park

The trainees were agree on the importance of environmental education in national parks in developing an awareness towards environment through gaining first-hand information about the park (its' elements, problems-solutions), which will result with environmental-friendly behaviours such as respecting it and avoiding those that can harm it; at the end will end up with sustainable behaviours of effective use of cultural and natural resources for next generations (that will help also rural development):

"What is the importance of Natural Park for that region? What are the problems of the region? How can it be solved? Different disciplines are important for various information sharing. It is based on practice and observation. Participants could transfer what they got from the education into real life. Even at the end of each education participants could have prepared a common project or work on a real project, they could have prepared a presentation/poster based on the project. These could have been nice." (Trainee 1)

“For the principle of Sustainability; keeping alive, leaving (it) next generations.” (Trainee 2)

“The aim of the program is to get the participant to comprehend the importance of cultural and natural resources, and to gain a general environmental awareness in protection and effectively using them.” (Trainee 3)

“The general development of the area is one of the important aims; it should be given a place. Because quite the region is poor. ... because our people can not see the future and I think they if they aim them there will be a great improvement. Because this is one of the small developing places.” (Trainee 4)

“I mean plant structure, animals living there that we call as biologic diversity, soil structure can be gained. Behaviours toward their protection can be achieved. The sense of responsibility towards them can be earned.” (Trainee 5)

“I think national parks are very important in comprehending the importance of nature preservation, leaving a clean society, environment, and nature for new generations so that they can take advantage of these beauties, and in developing a sustainable environmental consciousness.” (Trainee 6)

7. The subjects, activities, and methods of an environmental education in national park

The trainees' ideas on the preferred subjects for an environmental education in national park program showed resemblance to the topics they were given during the course. In fact as one of the trainee told:

“The subject titles in the Scientific and Technological Research Council of Turkey's education seemed diverse and enough.” (Trainee 1)

Others give the names instead, for example:

“Geomorphology, hunting-wildlife, ecosystems, preserved area management, biologic diversity.” (Trainee 2)

On the other hand, some of the trainees needed more information and experience in many topics, such as the characteristics of the park, and rural development studies in the park

“... the characteristics of the park, and the ones that differ from the other national parks, should be given by comparing. The cultural and natural resources of the national park in other words what makes it a national park should be given in detail.” (Trainee 3)

“The subjects should be one geology, two how the studies coordinated with the public are being executed should be told. Three the regulation of people's means of living or development should be told. Four first-aid, five plants, when I say plants (I mean) edible, not edible.” (Trainee 4)

The trainees' ideas on the preferred activities for that kind of program were similar to the activities they participated during the course, such as field-trips; ecotourism; orientation to the area and course participants. On the other hand some new activities were suggested. These were project development; scientific studies, i.e., on human-nature relationship. One trainee also suggested that the activities should be informed to the participants so that they will prepare the instruments they may need during the course.

“Apart from (this) if a small project study is done in group, it will beneficial to transfer what was learned into life.” (Trainee 1)

“... For example a binocular. If these are informed us previously or a pre-presentation is done through the internet, I think people will adapt here more.” (Trainee 4)

Like their responses to the preferred subject titles and activity names, the trainees summarized the teaching/learning methods of the course as printed and visual materials, active learning, practice (field-trips,

experience based, learning by doing, observation). One trainee's answer was interesting in terms of outlining how a field-trip should be in terms of overlapping what is told in the theory and what can be used as a separate activity:

"Of course a good planning here is important first of all. Entrance to national parks, in what way, and is' duration should be planned well. I believe that with a good plan, program a more effective study can be done. Undoubtedly visual elements will be used in theoretic lessons. I believe that when (the trainee) goes to the nature, climb to the national parks by combining the visual elements in the class and the real scene in the national park will be more effective." (Trainee 6)

8. The evaluation of an environmental education program in national park

The trainees reflected that there can be different evaluation activities for various purposes: consisting mostly of post-tests for example after the course as a whole evaluation of the program in the form of questionnaires or the evaluation of what is learned in the form of a basic knowledge tests. One trainee suggested an evaluation that will help to assess participants' intention to come to the course. When we think about the evaluation method applied in the course, we can see that in fact from these methods, questionnaire and intention letters were already asked from the trainees in the course but a knowledge test has not been applied before and was new to the course program. Two trainees recommended process-oriented assessment techniques that can be implemented on the field after gaining enough knowledge and experience especially from the theory part in the class as an application of information:

"... But I think we made an evaluation. Why do I think that I did? (We) tried to present a sample we took after drying it. This also shows that we did an activity consciously and evaluated it. Am I clear? In other words practically I think we could do it." (Trainee 4)

"According to me since it is both theoretical and practical, measurement and evaluation should be done in theoretical, (they) can be done in practical but how does an evaluation make in practice? If you introduce the structure and fauna there, you can make observation on site as a practice." (Trainee 5)

9. The program's effect on meeting of trainees' expectations

The trainees agreed that the program met their expectations, developed their consciousness toward environment and their general knowledge about the area. The elasticity of the course rules created a positive learning environment for the trainees. On the other hand, the scientific names of plants were forgotten.

"... Additionally I forgot the names of botany-plants and some information that are beyond my subject area. On the other hand I agree that other parts helped me." (Trainee 5)

10. Trainees' suggestion of the program to their friends or people

The trainees had the same opinion on advice. They told that since the program develops consciousness and sensitivity towards environment, they will recommend it to other people. One trainee emphasized that the program is a kind of group activity and he advises it. Another told that she has already informed many people and written an introduction to her bulletin:

"After education I recommended this education to many people. I wrote an introductory article to our News Bulletin because I want that people who are sensitive to this issue and who have concerns, troubles towards their environment in- or out of- their discipline level to get benefit from this kind of education. Seeing by knowing-I do not want that any people is deprived of this sense." (Trainee 6)

11. Trainees' suggestions or comments

The trainees commented on several things that have already given in the previous parts. One trainee's response had an original contribution to this part. He recommended that the education should also give both

background information and application of the use of the park's living and nonliving elements for economic purposes. He thought that the trainers will gain financial benefit from this activity and can organise their future programs:

“When conducting environmental education in national parks, at the same time during this education, a training should be given on how the plants growing in national parks, having economic importance or those natural waste under the forest such as tree leaves, coniferous plants or stick and twig remnants etc., can be perused and its’ practice too should be done, because this products that stayed alone there in the nature inhibit the growth of plants, small plants under tree, kill them. Therefore they should be collected with a proper method and be utilized. Anyhow an economic outcome of these studies should be found too. With a lesson and application to be given how do these be and in what way do (they) be collected? With which technique and with what method do these under forest waste and other plants with economic importance be collected and be packed? These under supervision of the experts should be evaluated anyhow and surely and for sure an economic outcome should be gained from these educations so that it becomes a financial source for and a support for new educations. I think that by all means these studies should produce economical activity, an economic value.” (Trainee 7)

Conclusion & Interpretation

This qualitative study was conducted with six trainees participated to the ecology based nature education in conservation areas program organized by the partnership between Kastamonu City Governorship's Environment and Forestry Directorate and the Scientific and Technological Research Council of Turkey in two terms on July and August 2005 in Kastamonu, Turkey. Interviews were carried out with the trainees in order to get their views on an effective nature education in national park. Specifically, the trainees were asked to evaluate the current program in terms of the degree to which it could meet their expectations and to explain their ideas on the role of the program on increasing environmental consciousness and develop positive behaviours; the characteristics of trainee and trainer group; the aim, objective, subject, activity, method, and evaluation techniques of the program; recommendations to other people. According to the participants, they have an individual interest in environment and environmental issues. It can be said that intention when considered as an attitude element is a necessarily condition to participate in a national park education program. On the other hand, participants' expectations about the teaching/learning methods and activities relate with the visual qualities of the national park, because this education takes place in nature and participants wanted more practice, field-study, and observation. Education in national park also inspired the participants and developed their consciousness toward environment. As a conservation area, national parks can be regarded as an education source where the importance of natural heritage and what should be done to protect it are taught (Pellegrini Blanco, 2002). Course subjects gave the participant a basic training on national park concepts and ecotourism or other rural development case studies worked well on understanding human-environment relationships. The participants agreed that the education should be given to all people regardless of their status, but they gave priority to people having education careers because they thought that educators will train more people. The participants also thought that experts from universities and NGOs should give the education. In fact no trainee implied the park inhabitants as target group for the education. It is suggested that the opinions of park inhabitants should be included in national park management (Adams, as cited in Deniz et al., 2008). Park inhabitants' utilisation of forest and agricultural fields should be learned to decrease tensions between park and its' inhabitants (Harada, as cited in Deniz et al., 2008).

While the present subjects and teaching/learning methods were found sufficient by the participants, new activities such as development of ecotourism, rural development, or human-nature relation projects were asked to be included in the education. The participants also proposed a process-oriented evaluation technique, since they saw that they could assess their learning of theory with practical activities, but there was no measurement to assess what they gained from the practice. Since the trainees were satisfied with the education, they would ask other people to participate it. This situation can be measure of a general effectiveness of the education. As outlined beforehand as an alternative activity and evaluation the use of projects, and as final contribution of a trainee about the use of resources, natural park education should also include economical importance of park resources. As it is suggested an environmental education in conservation areas can be main device for the management of these places it can also

provide attitude change that give a better life standard for all individuals of the society (Pellegrini Blanco, 2002). It is claimed that outdoor education helps people to develop an environmental consciousness (Howe & Disinger; Yerkes & Haras; as cited in Erdoğan & Özsoy, 2007), and responsibility due to having a natural setting that allocates their active participation to activities and increase their interest towards the natural environment (Matthews & Riley, as cited in Erdoğan & Özsoy, 2007). Increased interests and curiosity about nature stimulates people's learning about environmental issues and motivates them in taking environmentally responsible actions (Dresner, as cited in Erdoğan & Özsoy, 2007). As people gain more information on the function of ecosystems and on environmental action strategies, they develop more environmentally responsible behaviours and show more action towards these issues (Dresner; Palmeg & Kuru, as cited in Erdoğan & Özsoy, 2007).

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EXAMINING FORMAL, INFORMAL-OUTDOOR SCIENCE EXPERIENCES, AND INTEREST IN SCIENCE AMONG TURKISH PRESERVICE ELEMENTARY SCIENCE TEACHERS

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Abstract

The purpose of this research was to examine Turkish preservice elementary science teachers' past formal and informal science experiences and their interest in science. The sample was made up of students (N=93) who took science laboratory course in Spring 2007 and Fall 2008. At the beginning of the semester students were administered a self-report science background survey. The purpose of this survey was to identify formal and informal background experiences of students that might affect interest in science. The findings indicated that students' overall interest in science was low and their formal school science experience, especially elementary school science experience was negative. Also students' involvement in non-school science activities was not positive. The most frequently mentioned activities were watching science programs on TV, playing with LEGO bricks, making models, making science collection, taking things apart, care of animals, and star gazing. Implications will be discussed.

Introduction

Research studies and autobiographies of such eminent scientists as Albert Einstein, Robert Burns Woodward, Charles Darwin and Richard Feynman suggest that rich and playful early childhood experiences with science had an impact on their careers and interest in science. The research studies examined the influence of schooling on the vocational choice of university professors from various fields of science and ascertained that outdoor explorations, such as collections, museum visits, LEGOs, and other construction toys, had more influence than formal schooling (Rowsey, 1997; Jarrett & Burnley, 2007). Research with elementary school children indicated that their science experiences inside and outside of the school played a key role in the development of their interest in science (Joyce & Frenga (1999). De Laat and Watters (1995) studied the origins and changes in preservice teachers' science teaching self-efficacy and found that teachers with high personal teaching self-efficacy had been interested in science for a long time and had a relatively strong background of formal and informal science experiences. Sampson (1992) found that preservice elementary teachers' non-school experiences stimulated their curiosity more than their science classes in school. In another study, Falk (2002) surveyed adults over 18 years old on the contribution of non-school sources for learning science and found that a significant percentage of science learning occurs from the following, in order of significance: books and magazines, life experiences, TV, school science courses, museums and zoos, on the job, family and friends, radio and audiotapes.

Rationale

Educational philosopher Dewey (1913/1979) and psychologists Krapp, Hidi, and Renninger (1992) describe effective teachers as interested in their subject and demonstrating enthusiasm for teaching the course content. However, there is little empirical research on where, how, and when teachers' interests develop, especially their interest in science. The purpose of this study is to ascertain the connection between the quality and type of background science experiences and preservice teachers' interest in science. This study addresses the following

research questions: What science background experiences (school, home, and informal education) and how do those experiences affect initial interest in science?

Methods

Participants were preservice elementary science teachers at Uludag University in Bursa, Turkey. The students graduated from a science and mathematics branch of high school where they took several science courses every semester. Participants consisted of 93 students (49 female, 44 male). In order to determine, students' past formal and informal science experiences, Science Background Experiences Survey (Bulunuz, 2007) was adapted and translated into Turkish. The survey consists primarily of items on a five point Likert scale in which students rated their background experiences in elementary school, middle/junior high school, high school, and college/university. At all these grade levels, the students were asked to identify their "best science" course, rate on the following dimensions: *enjoyment, fun, interesting, hands-on, student input, learning, and understanding emphasis on of that course*. In addition to ratings, students were asked to write comment on their best science course experiences. The assumption was that having at least one good course might be influential, even if other experiences are negative or neutral. Students also rated parent support and non-school experiences and identified play and recreational activities important to their childhood or youth. In addition to science background survey, at the beginning of the semester, students were asked to rate their overall interest in science in a five point Likert Scale. High interest students are those who gave a response of 4 or 5, and low interest students are those who gave a negative or neutral response (1-3).

Results

The frequency count revealed that about 70% of the participants came to the teacher preparation program with low interest in science and their elementary school science experiences were negative. In their comments students stated they had very little science or their science experiences were uninteresting. For instance, one participant stated about middle school science course that: "*I didn't enjoy the science course because it was very theoretical and memorization emphasized.*" These results are similar to the studies found relationships between the quality of school science experiences and interest in science (De Laat & Watters, 1995; Joyce & Frenga, 1999). The comparisons of science courses experience from middle/secondary school through university indicated that there was not much difference. The dominant "best course" for students in both high school and university was biology and a few students participated in science fair project. The ratings of "best courses" appeared to be similar between middle/secondary and university. In their ratings of their "best science course," neutral levels of *enjoyment* of the course corresponded to neutral ratings on course descriptors of fun, interesting, hands-on, how much they learned, and emphasis on understanding. The students input in science class were negative at all grade levels suggesting that enjoyment decreased as students had less control over their learning, a situation typical of introductory lecture courses with cookbook-type labs. This importance of student input is consistent with philosophers (Dewey, 1979) who accepted the premise that every student comes to the classroom with different background experiences, and discovery should start with students' curiosities, interests, and experiences that are salient motivators for learning.

To describe non-school science experiences, students were asked to rate their parental support, school field trips, and non-school experiences (gardening, raising plant and animals, nature walks, making science collection, etc.). The result of their ratings indicated that parental support in establishing interest in science was negative ($\bar{X}=2.15$, $SD=1.32$). School fieldtrips and non-school science experiences were slightly over neutral. To determine involvement in non-school science activities, students were given a list of science related activities and asked to check the one they experienced in early childhood and youth. The most frequently mentioned activities were visit to zoos, nature centers, aquaria, LEGO bricks, making models (e.g airplanes, boats), making science collections, and taking things apart.

Conclusions and Implications

One of the implications of this research is that it is important for people to have positive science experiences in schools and involvement in out-of-school science activities for the development of interest in science. These findings have implications for parents, school systems, curriculum developers, and teacher preparation programs. Parents should be aware of their own impact in promoting their children's interest in science by doing home-related activities such as experimenting with kitchen chemicals, looking at things under a microscope, taking care of plants or pets, playing with LEGO bricks, and making science collections. The tendency for mean ratings of the "best science course" descriptors to be negative or neutral from elementary school to middle/high school course implies that there is a need to examine and possibly revise science teaching curriculum. Students' ratings for the science content courses at the university indicated that there is much emphasis on memorization, little fun, few interesting hands-on science activities, and low student input. The science content course should model hands-on inquiry science teaching practice in order to develop interest in science and deepen preservice teachers' understanding the processes of scientific inquiry.

This study relied on participants' memories and their comments about their background science experiences. Further research studies on background experiences could be conducted with current elementary middle school or high school students who can remember many aspects of their science course experience in school. Additional research could also include interviews with students, parents, and teachers.

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PATTERNS OF TEACHERS' THINKING ON SCHOOL VISITS TO A SCIENCE MUSEUM

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Abstract

Science museums are important and acknowledged cultural and educational resources. Schools and teachers usually place a high educational value on visits to science museums, but bibliography indicates that most teachers do not usually define the specific aims of a visit or prepare activities before, during or after a visit. The aim of the study is to analyse teachers' conceptions of the aims of school visits to science museums, as well as preparation and processing after the visit. A group of 158 teachers from about 100 different schools took part in this work. Of the total teachers, 87 were primary school teachers and 71 secondary school teachers. These teachers were interviewed at the museum with a protocol in the form of a semi-structured interview. The results of the study show that most teachers do not apply their professional pedagogical knowledge to the organisation of a visit. The data indicates that three quarters of teachers feel involved in a visit at organisational level and consider it as a recreational experience in the field of science but do not consider it as a teaching tool for school. Contrary to some results from the research, we found no significant differences between the aims of a visit in primary and secondary teachers.

Introduction

Science museums are important and acknowledged cultural and educational resources. Schools and teachers usually place a high educational value on visits to science museums, but bibliography indicates that most teachers do not usually define the specific aims of a visit or prepare activities before, during or after a visit (Cox-Petersen et al. 2003, Griffin 2004, Tal et al 2005). Lemelin and Bencze (2004) point out that a significant conceptual development will only occur when a visit is clearly connected with learning aims which link school activity with the museum visit. This involves considering the importance of teachers in organising the outing with their students, in the preparation and adaptation of what the museum has to offer for their own teaching objectives (Falk y Dierking 2000). From this point of view, an initial step to getting teachers involved in this task using visits to science museums as a teaching tool will be to know what teachers think about school visits to science museums and what role they play in the visits made with their students. In this work we are going to deal with the part corresponding to teachers' thinking on the objectives of a school visit to a science center and activities which they design and develop before and after a visit.

Rationale

In the Basque Country (Spain) there is one science museum which was inaugurated in 2000. The museum offers activities, workshops and guided visits for schools. This museum is different from other Spanish science museums in that it offers teachers educational materials which give information on the connections between the scientific content of the museum exhibits and the contents of the school curriculum (see website: <http://www.miramon.org/kutxaesp.nsf/fwHome?OpenForm>).

The museum management has repeatedly stated to us in conversations that one of its main challenges is to motivate teachers to get involved in visits. Our experience in previous works (Guisasola et al 2008) shows that when a teacher prepares a visit beforehand and guides his/her students in the activities carried out, the learning experience is more significant both for the conceptual and the affective and collective points of view. Therefore, the aim of the study is to analyse teachers' conceptions of the aims of school visits to science museums, as well as preparation and processing after the visit. The questions which have guided the investigation are:

- 1) What aims or motives do teachers have in a school visit to a science museum?
- 2) What connections do teachers establish between a science class and a museum visit? How do teachers prepare the connections between a science class and a museum visit?

Methods

An initial group of 158 teachers from about 100 different schools took part in this work. Of the total teachers, 87 were primary school teachers and 71 secondary school teachers (12-18 year old students). These teachers were interviewed at the museum with a protocol in the form of a semi-structured interview. The protocol was developed on the basis of a previous study with 57 primary school teachers from the Basque Country on their aims when preparing a school visit to a science museum/centre.

In the first part of the interview teachers were asked educational questions with content connected with the preparation for their visit. In the second part the teachers were asked to freely give the main positive and negative aspects of the visit and, possible activities after the visit.

After collecting the data, all the interviews and observations were transcribed and qualitatively analysed so that the relevant information for each question was classified and interpreted as a result. When grouping the data into categories we used as a reference the categories used in previous work which were clarified and reformulated during the analysis process (Kvale 1996). This meant identifying common trends and defining specific patterns and categories associated with a) the teachers' expectations and aims regarding a museum visit; b) the teachers' preparation for a visit before and afterwards; c) the degree to which a visit made was compatible with the recommendations of research into the teaching of science in informal contexts.

Results

The results obtained showed three categories of teachers in relation to the aims and connections with school teaching. Firstly, we had the category of the "teacher as an organiser" of a museum visit. This category was characterised by the consideration that their role was to organise the museum visit with the aim of the students having social personal experiences connected with science (60% of answers on aims). Notwithstanding their task finishing with the organisation of the museum visit, it will be the educational staff at the museum that will be responsible for the pupils during the visit. Therefore, they do not need to carry out activities with the pupils before and after the visit (56% of answers) or need to know what is on offer to schools (56% of the teachers) or the educational materials at the museum (70% of the teachers). The teachers in this category concentrated on the organisational and recreational aspects (45% of answers in positive aspects) and did not pay attention to the possible specific learning of scientific subjects or procedures.

We called the second category the "traditional teachers", those who are concerned not only about the organisational and recreational aspects of the visit, but also about experimentation (30% of answers on aims) and the learning of scientific concepts (53% of answers on aims). Teachers in this category thought that a museum visit was a good opportunity to "confirm" the theory seen in class. These teachers thought that a visit has a "clear" connection with the contents studied in class, but do not carry out specific activities to shown this "clear connection" (87% of teachers in this category). These teachers are grateful for the educational help given by the

museum during guided visits (41% answers in positive aspects) and the opportunities to see experiments and to carry them out offered by the museum (26% answers in positive aspects).

The third category was the so-called “innovative teachers” who are concerned not only about the recreational and experimental aspects, but also about the learning of specific concepts and procedures in the school curriculum. Therefore, they considered that they ought to prepare a visit so that the pupils can establish a bridge between the contents it is intended they learn and the experiences in the museum. The teachers in this category use a educational material supplied by the museum to prepare the visit (4.3%) and after the visit (4% in table 3). They are likewise concerned about knowing whether the students relate the contents of the curriculum to a visit (16.5% of answers in positive aspects).

Conclusions and Implications

In this study we have analysed the expectations of teachers in the Basque Country in connection with the sole science centre in this region. Therefore, the conclusions of the study may be restricted by the specific characteristics of the Museum. As described, it is a museum with visits guided by instructors and supporting educational materials for teachers relating to the contents of the museum and the school curriculum. However, the findings may be used to provide foundations for inquiry into teachers’ conceptions on science museums visits and determine their relevance in science teaching and learning.

Most teachers do not apply their professional pedagogical knowledge to the organisation of a visit. One of the reasons for this may be that they do not consider it part of their task as professionals. The data in our study indicates that three quarters of teachers feel involved in a visit at organisational level and consider it as a recreational experience in the field of science but do not consider it as a teaching tool for school (Cox-Petersen et al 2003). Very few teachers attempt to relate a visit to the school curriculum (about 5%). One of the reasons for this may be that teacher training programmes are based on classroom teaching but few programmes involve teachers in learning experiences outside the classroom (Griffin 2004).

Contrary to the results of Tal et al (2005), we found no significant differences between the aims of a visit in primary and secondary teachers. One reason for this fact is that the differences between primary and secondary schools arise within the context of the curriculum and only 5% of secondary school teachers and no primary school teachers design activities which link specific aspects of the museum and the curriculum.

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PART 4
SCIENCE CURRICULUM AND EVALUATION

THE RELATIONSHIP BETWEEN TEACHERS' BELIEFS AND THEIR PRACTICE: HOW THE LITERATURE CAN INFORM SCIENCE EDUCATION REFORMERS AND RESEARCHERS

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Abstract

To what extent can we believe teacher reports about their practice? The extent of influence of teacher beliefs on their practice is an important question for investigators and evaluators of educational innovations who use teacher surveys or interviews as their main method(s) of gauging teacher practice. This paper investigates what the literature has said about the relationship between teacher beliefs and their practice in the classroom. It aims to bring together the key findings from a review of the relevant literature, and to discuss its implications for educational evaluation and research in science education. Several studies have examined the relationship between teacher beliefs and practice. However, findings have not been consistent because it is complex. Some researchers have reported a high degree of agreement between teacher beliefs and the practice of teaching whereas others have identified some inconsistencies. Some believe direct observation of lessons and of teachers' decision-making and goals is necessary to know their beliefs. Few studies were found about beliefs in relation to specific subject matter knowledge and beliefs yet science teaching reforms are not likely to succeed unless some teachers' deeply held beliefs about science teaching and learning change. The paper discusses this issue.

Introduction

To what extent can we believe teacher reports about their practice? The extent of influence of teacher beliefs on their practice is an important question for investigators and evaluators of educational innovations who use teacher surveys or interviews as their main method(s) of gauging teacher practices. According to Pajares (1992), the investigation of teacher beliefs is a necessary way of educational inquiry for research and education. Being able to identify and describe the influence of teacher beliefs on instructional actions would deepen and enrich our understanding of the teaching process (Aguirre & Speer, 2000). This paper investigates what the literature has said about the relationship between teacher beliefs and their practice in the classroom.

This paper aims to bring together the findings and key points of a review of a significant part of the available literature associated with the relationships between teacher beliefs and their practice in the classroom, including the more recent research that has been carried out in this area and to discuss its implications for educational evaluation and research in science education.

In this paper, I will start with a discussion of the problem, then what the literature said about the definition of beliefs. After that, an argument about the relationship between teacher beliefs and practice will be presented. Some implications will be drawn and a conclusion will be presented.

What is the problem?

Because research in science classrooms often reveals unsatisfactory practice such as predominantly non-interactive approaches that fail to engage students (cf. Lyons, 2006), there is often intense interest in implementing innovations in science educational settings. However, at the same time, there are often concerns about that the ways in which an innovation is - or is not - put into practice by teachers (e.g., Cuban, 2001). One of the factors that is believed to influence the implementation and establishment of new activities in the classroom is teacher beliefs. For example, teacher beliefs about the integration of computers into primary school science may influence their teaching approach. However, a direct relationship between the two has been questioned, and, in fact, the question may be asked as to whether teacher practice is necessarily consistent with teacher beliefs. Therefore, in this paper, these issues will be investigated particularly in their application in the context of innovations in science education.

The question of the potential influence of teacher beliefs on their practice and the extent and direction of this relationship are important questions to explore in an area where teacher beliefs are much investigated. Aguirre and Speer (2000) have argued that knowledge about the relationship between teachers' beliefs and their practice in the classroom can increase both the breadth and depth of our understanding of how teaching proceeds.

Another reason for the importance of this issue is that it represents a possible threat to the validity of educational research based on teacher self-report (through either surveys and/or interviews), given that there may be inconsistencies between what teachers report, what they believe, and what they do.

From another perspective, "coherent belief systems" may be a research artefact, one researchers create "to interpret those of the teachers rather than actually being present and formative of teaching practice" (Kynigos & Argyris, 2004, p. 271). Kynigos and Argyris arrive at a point where they question the very concept of "teacher beliefs" and the nature of the influences such beliefs are thought to have.

What is 'belief'?

According to Mansour (2009), beliefs are one of the most difficult concepts to define. Although educational literature has paid great attention to teachers' beliefs, there is still no clear definition of belief (Savasci-Acikalin, 2009). As Pajares (1992) argued, "the difficulty in studying teachers' beliefs has been caused by definitional problems, poor conceptualizations, and differing understandings of beliefs and belief structures" (p. 307). Therefore, the definitions of beliefs have been varied in the literature. He suggested that researchers need agreement on meaning and conceptualization of belief.

A recent study (Mansour, 2009) indicates that because teachers' beliefs tend to be more experience-based than theory-based, "beliefs can neither be clearly defined, nor do they have a single correct clarification" (p. 35). Thus, different researchers gave different definitions for beliefs. For example, Pajares (1992) reviewed a literature of beliefs and reported that beliefs were defined in most studies as a 'conceptual tool'. He defined belief as an "individual's judgment of the truth or falsity of a proposition, a judgment that can only be inferred from a collective understanding of what human beings say, intend, and do" (p. 316). According to Aguirre and Speer (2000), current definitions of teacher beliefs found in the education literature focus on how teachers think about the nature of teaching and learning. In this context, beliefs are defined as "conceptions" (Thompson, 1992, p. 132), world views, and "mental models" that shape learning and teaching practices (Ernest, 1989, p. 250). Another researcher, Standen (2002), wrote that beliefs can be classified in terms of personal assumptions about relationships, knowledge and society; professional beliefs about teaching and learning; and beliefs about change and development.

According to Yero (2002), the confusion focuses on the distinction between beliefs and facts. She suggests that the key is to identify which statements frequently used in education are facts and which are beliefs. She defines beliefs in opposition to fact. Thus she defines facts as “statements that from a particular perspective are part of ‘consensus’ reality” (p. 21) and beliefs as “judgments and evaluations that we make about ourselves, about others, and about the world around us [and] . . . generalizations about things such as causality or the meaning of specific actions” (p. 21). For example, not everyone would agree that classrooms must be quiet for learning to take place while generally people would agree that the chemical formula for water is H₂O. Beliefs and knowledge will be discussed further after a discussion of the relationship between beliefs and practice.

A direct relationship between teacher beliefs and teacher practice

Several studies have examined the relationship between teacher beliefs and their practice. However, perhaps partly because of the variety of belief definitions in the literature, the relationship between teacher beliefs and practice is in question. The findings in the literature include some in science education which have not been consistent, with few studies being found about specific subject matter knowledge and beliefs (Mansour, 2009; Thompson, 1992; Pajares, 1992) and fewer about beliefs and goals (Lacorte & Canabal, 2005; Aguirre & Speer, 2000) or beliefs and emotions (Zembylas, 2005). Some researchers doing research in science and mathematics education reported a high degree of agreement between teacher beliefs and the practice of teaching (Aguirre & Speer, 2000; Ernest, 1989; Standen, 2002; Thompson, 1992) whereas others have identified some inconsistencies (Kynigos & Argyris, 2004; Lefebvre, Deaudelin & Loiselle, 2006; Zembylas, 2005). Kynigos and Argyris (2004) argue that the relationship between teachers’ beliefs and practices is a complex one, and that the researcher must question common assumptions made about it.

On the one hand, some literature on the relationship between teacher beliefs and their practice has found that teacher beliefs are consistent with classroom practice (Savasci-Acikalin, 2009). According to Thompson (1992), some studies support the claim that teachers’ beliefs influence classroom practices through interpreting meanings in the classroom. For example, Yero (2002) suggests that beliefs affect how teachers and pre-service teachers behave. She states,

If teachers believe a program they have been told to use is based on a solid foundation, and if the program is based on beliefs similar to their own, they will notice ways in which the program works. If they believe it is a waste of time, they will notice evidence supporting that belief. (P. 24)

Mansour (2008) studied the relationship between science teachers’ personal religious beliefs and their practices. The findings of his study suggest that teachers’ personal religious beliefs and experiences played a significant role in shaping beliefs and practices.

Lefebvre, Deaudelin and Loiselle (2006) study teaching conceptions and teaching practices with the ICT implementation process. Their findings were that teaching practices appear to be strongly associated with teachers’ conceptions of the teaching and learning process.

While these studies illustrated a direct relationship between beliefs and practice, several studies showed a complex relationship between them. Generally, it is difficult to develop a clear understanding of the relationship between teachers’ beliefs and their practice because “researchers have defined beliefs in terms of their own agendas and seldom explored the many possible interactions among belief sub-constructs or their connections to other cognitive or affective structures (Pajares, 1992, p. 326). As well, not all researchers agree that teachers’ beliefs offer greater insight into their practice. While some studies found that teacher beliefs have a significant relationship with classroom practice, others did not find a clear relationship between teacher beliefs and practice because of other factors. The next part presents some examples of the latter.

Complex relationship with other factors

The findings of a recent study indicate that the relationship between teacher beliefs and practice is controversial and has a complex nature (Savasci-Acikalin, 2009). The complexity comes from the fact that it is important for researchers and educators to think in terms of connections among beliefs not only in terms of beliefs as independent subsystems (Pajares, 1992, p. 327).

The argument about complexity of the relationship between beliefs and classroom practices is based on two assumptions (Kynigos & Argyris, 2004, p. 249), first, that teachers are professionals who make reasonable judgments and decisions within a complex and uncertain community, school and classroom environment; and second, that teachers' thoughts, judgments and decisions influence their classroom behaviour. However, teachers need significant assistance in identifying the disparity between their espoused beliefs and practices and to think through those inherent in new initiatives (Standen, 2002).

Several factors are believed to contribute to the complexity of the relationship between teacher beliefs and their practice such as their knowledge, goals, motion, pedagogy and instructional context.

Beliefs and knowledge

The relationship between beliefs and knowledge has been discussed widely in the literature. Beliefs are different from factual knowledge. Beliefs can be doubted more than facts. Based upon a literature review of beliefs, Savasci-Acikalin (2009) suggests that beliefs refer to suppositions, commitments, and ideologies and do not require a truth condition while knowledge refers to factual propositions and the understandings that inform skilful action and must satisfy "truth condition". Mansour (2009) provides a further distinction between beliefs and knowledge and says "while knowledge often changes, beliefs are 'static' [and] whereas knowledge can be evaluated or judged, such is not the case with beliefs since there is usually a lack of consensus about how they are to be evaluated" (p. 27). Therefore, many of the statements published in the literature about the educational environment are not statements of fact but rather of belief (Yero, 2002). For example, when someone says the use of computers is effective in science primary classrooms, he or she states his or her beliefs.

According to Pajares (1992), teachers' beliefs influence and play a fundamental role in their knowledge acquisition and interpretation, task selection, and course content interpretation. Mansour (2008) suggested beliefs controlled the gaining of knowledge but that knowledge also influenced beliefs.

Thompson (1992) argued that distinguishing between beliefs and knowledge was very difficult but that the distinction needed to be understood by educators and researchers since teachers may treat their beliefs as knowledge. Zembylas (2005) argued that teacher beliefs are important components of teacher knowledge and like teacher beliefs, teacher knowledge is needed in understanding teachers' teaching. In coming to an understanding of teachers' practices, the significance of teachers' knowledge and how it impacts on teachers' thinking should be considered (Standen, 2002).

Beliefs and goals

Although several studies contribute a great deal to our general understanding of beliefs and practice, Aguirre and Speer (2000) gave details of how those beliefs inform practice particularly in the formulation of goals in the classroom. They argue that in this way teacher beliefs play a central role in their practice. In their study, a collection of particular beliefs that are connected to one another and influence the formulation of a goal can be called a "belief bundle" (p. 333). A bundle includes a number of beliefs (beliefs about learning, beliefs about teaching, beliefs about science, etc. that go together). The belief bundles played a central role in the formulation of goals which influence teachers' actions during activities. See Figure 1.

Aguirre and Speer (2000) reported that saying ‘a teacher has a belief’ generally means that the teacher is behaving in a manner consistent with having such a belief.

Beliefs and emotion

The influence of deeply-held beliefs may be complicated further by a close interaction with emotions and feelings. Teachers’ beliefs and feelings are thought to be revealed during their lessons and to influence their decision-making (Kynigos & Argyris, 2004; Standen, 2002) and goals (Aguirre & Speer, 2000; Lacorte & Canabal, 2005). Zembylas (2005) argued that the concept of ‘emotives’, which “refer to emotional gestures and utterances” (p. 469) is helpful because the interrelations between beliefs, cognition and emotion can be identified “without being caught in the dilemma of making an ontological distinction among them” (p. 467). For example, if someone says “I am angry”, it does not mean the anger is the utterance, but there is something (internal) which is referred to. He says that there is an internal element to emotion, but it cannot be easily represented by statements or actions. However, its intensification or its rapid dissipation can result in expressing a feeling. In his study, Zembylas (2005) concludes that a teacher’s emotional development is influenced by her or his participation in particular forms of social and discursive practices at school.

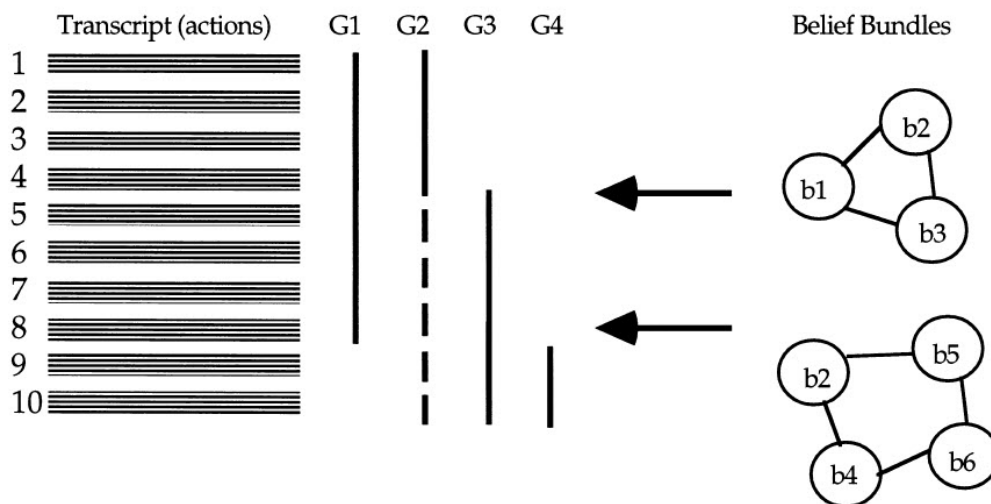


Figure 1: Graphical representation of a parsing with belief bundles (Aguirre and Speer, 2000, p. 334)

Beliefs and context

Some researchers argue that practice-related beliefs result from an interaction between teachers’ more general teaching-related beliefs and the institutional context in which the practice is located. A study by Lacorte and Canabal (2005), concerns the relevance of the perceptions and attitudes that teachers bring with them into the classroom. Richards (1998, as cited in Lacorte and Canabal, 2005) assert that “teachers’ beliefs result from the relationship between (a) the values, goals, and assumptions that teachers have about the content and development of teaching, and (b) the understanding of the social, cultural, and institutional context where teaching takes place” (p. 84).

Ernest (1989) argued that the autonomy of the teacher depended on three factors:

- 1.the teacher’s intellectual contents, particularly the systems of beliefs concerning the nature of teaching and learning;
- 2.the social context of the teaching situation, particularly the constraints and opportunities it provides; and
- 3.the teacher’s level of thought processes and reflections. (p. 250)

Like Lacorte and Canabal (2005), Ernest saw context as playing an important role in how beliefs are put into practice. He explained that the two key factors for a mismatch between beliefs and practices were: the powerful influence of the social context; and the teacher's level of consciousness of his or her own beliefs. He thought that this gap could be overcome, however. He noted that “higher level thought enables the teacher to reflect on the gap between beliefs and practice and to narrow it” (p. 6).

According to Yero (2002), “beliefs not only affect how people behave but what they perceive (or pay attention to) in their environment” (p. 24). Mansour (2009) found that some teachers’ beliefs are directly adopted from their background and their culture and science teachers’ beliefs and practice cannot be examined out of socio-cultural context. The study also indicated that most of the teachers’ religious beliefs which were often from informal sources (family, society, previous teachers, the media, etc.) could result in positive attitudes among teachers towards science and teaching science. For example, he argued that the Islamic religion encourages science and the gaining of knowledge.

Beliefs and pedagogy in conflict

Quinn and Wilson (1997) claim that the 'dichotomy' of beliefs and practices may stem from the difficulty inherent in changing teacher pedagogy. In their study, they concluded that although teachers have very favourable attitudes toward the use of writing in the teaching of mathematics, they are not putting those beliefs into practice; this may be because teachers do not have enough time for it (p. 19). Teachers are updating their beliefs regarding new ways of instructions but they are not changing their current ways of teaching. Kynigos and Argyris (2004) focus on teachers’ beliefs regarding learning situations, their pedagogical role and the role of the computer; their results “corroborate the view that espoused beliefs may be inconsistent with actions during classroom teaching practice” (p. 271). The study concludes that we learn much more when looking at teacher beliefs through their classroom practices in conjunction with what they express during interviews. The question arises of what happens when there is conflict between these beliefs and practice. For example, although several studies show that beliefs have a powerful impact on action, the study done in Turkey by Karaağaç and Threlfall (2004) illustrates that teachers’ goals, in particular when they are ‘imposed’ upon teachers, “can lead to classroom practices that conflict with their beliefs” (p. 143). According to Thompson (1992), as teachers interact with their environment, some teachers experience ongoing conflict between their beliefs and their practices and some learn to live with unresolved conflicts; others, however, appear to recognize their beliefs in responses to the pressures encountered in their teaching environment.

Further discussion and implications

There is still much debate as to whether beliefs influence actions or actions influence beliefs (Mansour 2009). Mansour reports that practice does not always come after beliefs, but may sometimes precede them. It should be noted that the relationship between teacher beliefs and their practice may be related to other factors, such as prior experiences both in and outside school. For example, Mansour (2009) argued that teachers’ experiences including teachers’ life-in-school experiences, life-out-of-school experiences and religious beliefs are significant factors in understanding the relationship between teachers’ beliefs and practices

Teachers may not be able to articulate fully the beliefs or theories that underline their practice or even be aware of them. In a seminal paper in the area of the relationship between beliefs and practice, Argyris and Schön (1974) argued that the theory that actually controls someone’s actions is their “theory-in-use”, which may or may not match their “espoused theory” (p. 7). They wrote that learning what people's theory-in-use is is not simply a matter of asking them, but their theory-in-use must be constructed from observations of their behaviour. They also argued that deep, lasting change must therefore involve more than what they call “single loop” learning. As well as underlining the complexity of the relationship between beliefs and practice, this suggests much care must be taken in the use of surveys and interviews to understand teaching practice.

Ernest (1989), states that teaching reforms require changes in teachers' deeply-held beliefs about teaching and learning. If this is the case then both educational innovators and educational researchers need to consider the issues raised by this review of the relationship between teacher beliefs and teacher practice. The study of the influence of teacher beliefs on teaching and learning in classroom situations may be a means to develop understanding of teachers' strategies and interactions in the classroom. Aguirre and Speer (2000) stress that people know more than they can tell and more than their behaviour consistently shows. Thompson (1992) concludes that teachers need to be helped to explore ways to examine their beliefs and practice. According to Pajares (1992), research on teacher candidates' beliefs would provide educators with significant information to help determine curricula and program direction.

An understanding of the relationship between teachers' beliefs and their practice can assist in determining their professional development needs. For example, as Mansour (2009) says, understanding the experiences of in-service or pre-service teachers will be an important task for teacher educators prior to the design of programs for science in-service teachers and pre-service teachers.

Conclusion

In conclusion, it is important for both reformers and researchers to understand the complexity of the relationship between beliefs and practice. In general, this review shows three perspectives on this relationship: teacher beliefs as influential on their practice; teacher beliefs as a weak influence on their practice; and the relationship between teacher beliefs and their practices as a complex one.

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GREEK TRENDS IN CROSS-THEMATIC-INTEGRATION OF CURRICULUM AS IN UNIFIED TEACHING OF NATURAL SCIENCES

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Abstract

The cross-thematic integration as a concept has its roots in a movement that had earlier questioned the choice of traditional curriculum, which dominated in Europe and America throughout the 20 century. It was a subject of debate in Greece, especially in recent years because of its introduction both in formal and in non-formal education. In the context of aid and support of cross-thematic integration for a more widespread use in formal and non-formal Secondary Education, in our paper we will discuss the different forms of cross-thematic approaches in Secondary Schools and Second-Chance-Schools respectively. While the introduction of cross-thematic integration in formal education, under certain conditions, can contribute to changes towards integrated teaching methods, the prominent role of an integrating Scientific Literacy adopted from the beginning by the Second-Chance-Schools, gives evidence of a holistic approach of learning.

Introduction

The introduction of cross-thematic integration in nursery, primary and lower secondary education in Greece coincides with the changes taking place in the new curricula in our country.

A Curriculum, in generally, should reflect and remain aligned with the needs of society, so that when there is a mismatch between the aims of the school and the needs of the respective society, an urgent need raises to reform that Curriculum (Vrettos, Kapsalis, 1999).

During the 1960s and early 1970s many OECD countries introduced remarkable innovations in the content and methods of teaching. Curricula were reformed and new approaches of teaching and new subjects were introduced in order to face the changes in the industrialized societies and the increased number of students drawn from all sectors of the community (Skilbeck, 1990).

Although it is not a new idea, the demand for cross-thematic-integration in curriculum rises up again by the end of the '80s. Moreover the curriculum integration has become very popular among educators in recent years. Educators cite a variety of justification for this approach, e.g. psychological/developmental, sociocultural, motivational and pedagogical. So, for example, researches in cognitive psychology show that the individuals learn better when encountering ideas connected to each other (Mason, T. C., 1996).

Not much empirical research studies that have been conducted. Most of them however supported curriculum integration. It appears that thematic units increased interest in school and had a positive result on students attitudes (Bragow, Gragow and Smith, 1995). Furthermore curriculum integration helps students make connections among concepts (Berlin, 1994).

These research findings, however, couldn't lead to generalizations because of the lack of an operationalized definition of curriculum integration. A coherent definition of curriculum integration is necessary and can be used as basis for designing and interpreting results of research (Czerniac C. M., 1999). Another problem is that because of

the structure of the school teachers have limited time to integrate (Venville, Wallace, Rennie & Malone, 1998). They also need special education about how to integrate across the curriculum (Berlin, 1994, Mason 1996).

The developments made in science education research during the last decade revealed new approaches about learning, which influenced the curriculum and the teaching. Constructivist learning theories suggest that learning is occurring when information is embedded within meaningful contexts. Adopting a constructivist view of learning has also effect to our view of the curriculum. According to this point of view, the learner constructs his or her knowledge depending on what the learner brings as “ideas” about natural phenomena (Driver, R. Oldham, V., 1986).

Over the past twenty five years the new trends in physics education especially at the secondary level have revealed a more child-oriented and activity-based classroom and have included more attention to student-relevance (Lijnce, P.L. et al., 1990). We can say that in general, the new trends in science education research which give more emphasis on technological and social aspects, scientific literacy, popular understanding of science, science for all and constructivist approaches lead us to integrated curriculum (Kokkotas, P. Piliouras, P. 2003).

So, Scientific Literacy is evolving to a main tendency in Compulsory Education. This tendency focuses on the acquisition of knowledge related to everyday life and emphasizes on the improvement of scientific skills in order to help students deal with everyday problems (Koumaras, Seroglou, 2008).

In our country the cross-thematic integration of curricula, was recently introduced in compulsory formal education, which is represented through our well known ordinary schools, while in non-formal adult education, in the example of the Second Chance Schools, cross-thematic and interdisciplinary integration is a structural component of the curriculum.

The cross-thematic integration of curriculum in Greece: Passage to a unified learning of Sciences?

In our country, because of the overall demand for reforming the curricula, the Ministry of Education designed through the Pedagogical Institute of Greece the Cross-Thematic-Integrated-Curriculum-Framework and the particular sub-curricula for nursery, primary and lower secondary education, applied since the school year 2007-08.

The Greek proposal for the framework as well as for the corresponding curricula, remains oriented to the logic of independent learning subjects, but provides interdisciplinary and cross-thematic integration through the correlation of knowledge on two axes, vertical and horizontal, which run throughout the curriculum. Specifically, on the vertical axis of correlation internal consistency and a smooth flow of knowledge between educational levels is intended, while the horizontal axis pursuits the aim to highlight common fundamental concepts between the disciplines (Makri-Botsari, 2006).

The Greek curricular framework is not purely cross-thematic-oriented, but it is characterized by interdisciplinary cross-projections. The cross-thematic integration is achieved through:

- small integrated activities in the classroom which are facilitated by special inserts provided in school books,
- teaching fundamental integrated concepts, which refer to each chapter, and found in many sciences such as: space, time, system, change, interaction, etc.,
- integrated activities and written work presented in the classroom by students, occupying 10% of the annual course duration,
- independent cross thematic teaching objects, such as Environmental Studies, Social and Political Education, etc. and
- the program of Flexible Zone with a duration of 2 hours per week, which has been gradually abandoned, specially in the teaching practice of the high school (Greek Ministry of Education - Pedagogical Institute, 2006).

At the same time in order to underline unifying aspects of science, concepts and principles, such as the concept of the natural system, the energy conservation principle, the model of the structure of matter and the relationship of microscopic and macroscopic phenomena, have been adopted as the main teaching proposal of physical science. (Antoniou, et al. 2007).

For the Greek scholar system this is a realistic option, leading to positive learning results under real conditions (Matsangouras, 2006) and an attempt was made to safeguard the positive elements of the curricula with isolated courses and to avoid disadvantages that may occur (Matsangouras, 2002). It was also attempted to link evaluation with the teaching process and its improvement, while the skills and attitudes of students are alongside evaluated (Alachiotis, 2002).

The question is whether cross-thematic integration, as introduced in secondary education in Greece, can help towards a unification in the teaching of Natural Sciences, and furthermore whether it is introduced in a non-mechanistic way.

In Greek educational practice a relatively small mobility is observed towards unifying the teaching of natural sciences and defining the integrative criteria. As an example, the experimental teaching of Integrated Science (Physics and Chemistry) has been implemented only for the 1st class of High School Students (age of 13) during the school years 1998-2000 with a total of 13.000 students as a part of a research carried out by the Pedagogical Institute (Tsaparlis & Kambourakis, 2003).

Ideas discussed in the Greek Pedagogical Science range from the adoption of a unitary school with integral content to the prospects of a partial integration of the teaching of Natural Sciences. Thus a limited trend towards unifying teaching of Natural Sciences is emerging in the Compulsory Formal Education in Greece. The introduction of cross-thematic integration in the curriculum, although accompanied by objections primarily related to the limited time available at school for their implementation, may in the future open a dialogue on teaching unification at least in some courses of Natural Sciences in the Gymnasium.

However, in any case of didactic unification, a plenty of questions arise about the needs and the unifying criteria.

The Scientific Literacy in Second Chance Schools: Scientific integration in a spontaneous cross-thematic learning process

The Second Chance Schools are designed for adult learners who have not completed their Compulsory Formal Education. It concerns an educational innovation, which in its first operational period was oriented towards the European model of non-formal Adult Education, affected however recently with major influences on its initial philosophy through our conventional Greek system of formal education (Studies Specifications, 2003, Ministerial Act, 2008).

The cross-thematic integration has been promoted through the teaching teams themselves to a dominant didactic concept, without an explicit mention of it in the initial regulatory framework for these schools. Keynote of the educative process is the concept of Literacy, which is implemented by the development and the acquisition of practical and social skills and abilities of the students in the systematic way of Multiliteracies (Dagdilelis & Hodolidou, 2003). The process of Literacy is concerned as a whole and it is distinguished, for methodological reasons only, in Language Literacy, Arithmetical Literacy, Information Literacy, Scientific Literacy, etc. Scientific Literacy is based on the assumption that the didactic approach of science should match modern integrative concepts prevailing in scientific theory and research. Thus some isolative separations usual in formal education such as between physics, chemistry, biology, geology, astronomy or geography are eliminated and science content is treated as a whole.

This unifying integration of knowledge is methodologically supported by the cross-thematic and interdisciplinary teaching practice, prevailing in the Second Chance Schools. In this way learning bridges are established between environmental education, social and economic dimension of natural sciences, their history and their cultural significance.

A very important role in the Second Chance Schools owns the relationship between Scientific Literacy and the Information Technology, regarding the content as well as the methodology. The use of Information and Communications Technologies supports an intense teaching and learning process concerning the main unifying concepts of Scientific Literacy, while methodologically it encourages the experiential approach of knowledge. Thus both Information Literacy and Scientific Literacy emerge together as a vehicle moving on a double route: on one hand it supports learning in science, while on the other it earns from the necessity of Scientific Literacy to implement experiential learning by using Information Technologies.

Discussion

We note that the general trend shown in the Natural Sciences for cross-thematic integration in the curriculum, and integrated teaching, benefits from designing curricula taken as a component the cross-thematic integration. We believe that cross-thematic integration, as introduced in the Greek formal education by the curriculum framework, through options based on local circumstances and the maintenance of distinctive separate subjects, can be a conditional step towards adopting more advanced cross-thematic curricula.

On the other hand, Scientific Literacy applied at the Second-Chance Schools, is by its nature unifying and thus achieved a didactic unification and gives evidence of a holistic approach of learning.

However, in terms of formal education, for the amount of cross-thematic integration provided in the curriculum to effectively been transferred into educative practices, a number of factors must be taken into account, that would strengthen the results of such a transfer.

Therefore, to have results in the aspect of holistic forms of teaching, cross-thematic integration should be linked to a series of changes - some have already begun, but not as well established – like training of teachers in assessment, focusing on the implementation of quality assessment for cross cutting work plans and laboratory exercises. Furthermore changes are required to prevent the memorization of knowledge and to eliminate the attitude of “grade hunting”, to reduce the amount of learning material, to introduce new teaching methods to be adopted by all teachers, to improve the scholar infrastructure providing new technologies as part of the educational process.

Last but not least, education could not maintain its traditional isolative categories in an historical period that asks more and more for unifying physical theories. The influence of new ideas and trends for the physical sciences will result to quick reflection on Science Didactic.

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TEACHING SCIENCE IN THE IRISH TRANSITION YEAR: A WASTED OPPORTUNITY

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Abstract

The Transition Year Programme (TYP) is an optional year between the Junior and Senior cycles in Irish second-level schools. This year offers schools the autonomy to design their own TYP curriculum. Our study aims to investigate how this is being done in relation to Science. Osbourne and Dillon (2008) note that “the standard school science education has consistently failed to develop anything other than a naïve understanding of the nature of science”. Transition Year offers an opportunity to develop this naïve understanding into a real interest and passion for the subject, moving away from high dependency on rote learning into learning beyond the classroom. This study examines how teachers are using the opportunity of an open curriculum in TY to teach science, their teaching methods, what resources they are using and their educational philosophy. Our results show that many are not using this opportunity properly, with 25% of students not experiencing all three sciences in the TYP. A majority (62.5%) of teachers, unsure of how to use this year, and unaware of many available resources, are reverting back to the Leaving Certificate Science syllabi, something specifically forbidden in the Transition Year guidelines. (Department of Education, 1993)

Introduction

The study of Science in Irish Schools is declining. Irish students are discouraged by an unexciting syllabus and outdated assessment methods. The Irish Transition Year Programme offers an opportunity for teachers to throw off the constraints of both the syllabus and assessment, and to utilise the year to change students' attitudes towards Science. Yet many teachers are unable to achieve this. As the saying goes ‘old habits die hard’, and during a time where more and more teachers are being pressured into ‘teaching towards the exam’ it is becoming increasingly difficult for teachers to find both the time and the energy to be innovative in the classroom.

Science in Ireland

Ireland is experiencing low numbers of students taking Science at second level; particularly in senior cycle Physics and Chemistry (see Figure 1). “The drop-off in students taking science from junior to senior cycle at second level is dramatic.” (Royal Irish Academy, 2005, p.5). The Task Force Report on the Physical Sciences (2002) found that “Two influences for low uptake of the physical sciences are the perception of the science subjects per se and the perception of science related careers. Many Leaving Certificate students say they did not choose physics or chemistry because of the difficulty of the subjects” (Department of Education and Science, 2002) Student perception of science as a difficult, complicated or boring subject appears to be influencing its take-up at Leaving Certificate level. Science, a subject aimed at making the world clearer and

developing awareness is considered by many students to be too abstract and complicated. (Mathews, 2007) It was noted in the 2008 Forfás Annual Competitiveness Report that of 21 countries surveyed, only three countries allocated less time to teaching Science than Ireland. (National Competitiveness Council, 2008)

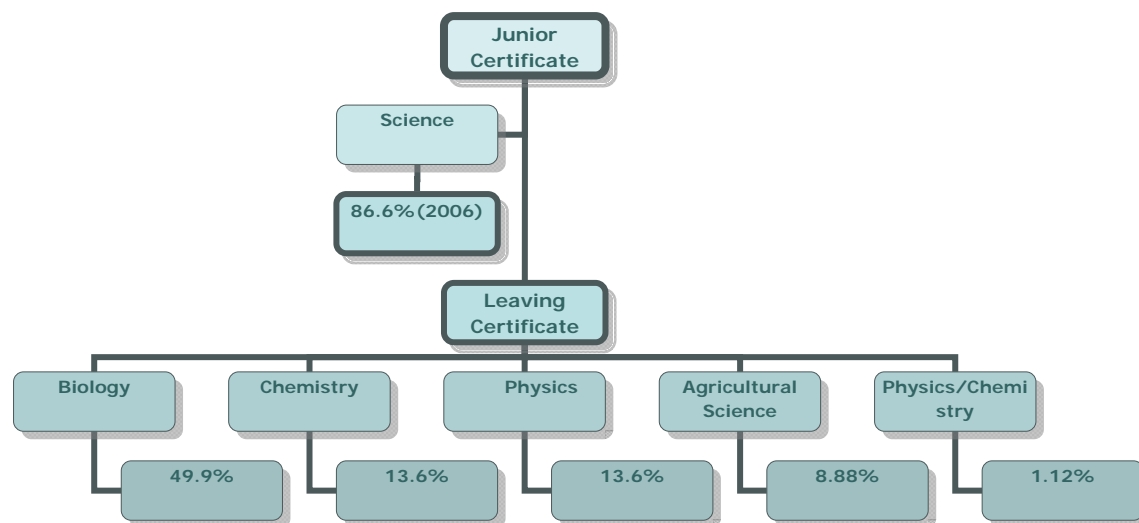


Figure 1. Percentage of student drop-off from Junior Certificate Science to the Sciences at Senior Cycle from 2006-2008

In Ireland Science is not a compulsory subject at any stage of the second level education system, unlike many European Union (E.U.) countries. Yet, *“Ireland’s education system has played a key role in our economic transformation by equipping the Irish workforce with skills and qualifications that supported the growth of our internationally trading manufacturing and services sectors”* (National Competitiveness Council 2008, p.11) Figure 1 shows that the 86.6% of students who take Science in the junior cycle falls off dramatically in the senior cycle, particularly in Chemistry (13.6%) and Physics (13.6%).

The Irish Transition Year

The Transition Year is an optional one year programme offered to students after they have completed their Junior Certificate, but before they enter the next examinable stage (the Leaving Certificate cycle) of their second level education. The Transition Year Programme was initially introduced to Irish second level schools in 1973. In the school year (September – June) 1974/75 a pilot programme was launched. This programme was initially piloted by three schools and involved sixty six pupils. It was concerned with both the early school leaver, and students who planned to complete their Leaving Certificate but felt unready to do so immediately after the Junior Certificate. (ASTI, 1991, p.3) It was first introduced in recognition of:

- The need to encourage personal and social development
- The right of all student to a six year post-primary education
- The fact that Irish children leave second level school at a younger age than their European counterparts
- The failure rate at third level
- Employment prospects at that time

(Transition Year Second Level Support Services, 2006)

Transition Year was offered to all schools in the year 1994 and has since been known as the Transition Year Programme (TYP). The TYP has been going from strength to strength with three quarters of schools offering the year and half of students taking it, as can be seen in Table 1.

Table 1. Current Uptake of the Transition Year Programme

Year	Number of Schools offering Transition Year	Percentage of Students taking the Transition Year
2006/2007	524 (71.3%)	46.7%
2007/2008	540 (73.7%)	47.1%
2008/2009	552 (75.4%)	50.7%

The mission statement of Transition Year is “*To promote the personal, social, educational and vocational development of pupils and to prepare them for their role as autonomous, participative, and responsible members of society.*” (Department of Education and Science, 1993, p.1). The year is designed to act as a bridging year between the two examinable cycles of second level education. It was designed to enable students to move away from the highly structured, formally examined education programme on offer throughout the Irish schools system. In other words, to provide “*a bridge to enable students to make the transition from Junior to Senior cycle. It encourages personal and social development and recognises the need for students to grow in independence.*” (Transition Year Second Level Support Service, 2006) Transition Year was designed to bridge the gap between Junior and Senior cycle education while promoting a wide range of experiences and competencies, see Figure 2. (Smyth, 2004)

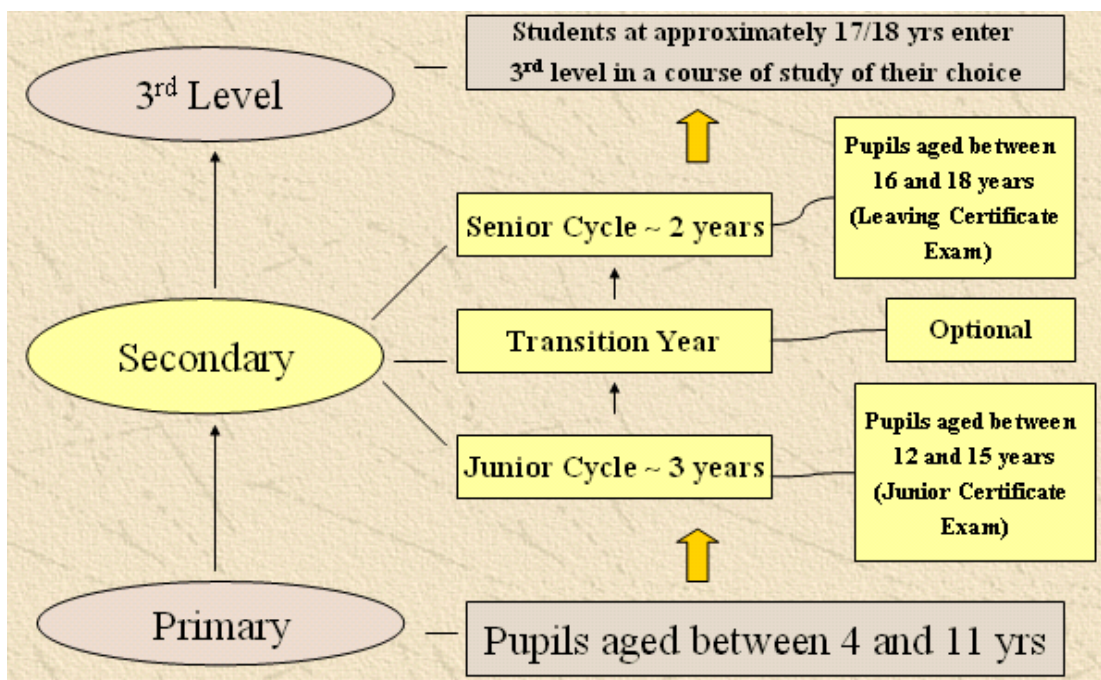


Figure 2. The Irish School System (Childs and Sheehan, 2009)

Figure 2 represents the structure of the education system in Ireland. Students begin their second level education in the Junior Certificate cycle - this is a three year programme culminating in a state examination.. It is at this stage that students may decide whether to proceed directly to the two year Leaving Certificate cycle or whether to move to the Transition Year programme (provided their school offers the Transition Year programme). The Transition Year then provides a year without the constraints of a prescribed curriculum for the students to experience aspects of adult and working life, before making their subject choices for Senior Cycle, the Leaving Certificate programme.

Rationale

The Irish education system is “*highly standardised with nationally specified curricula and examinations at both Junior and Leaving Certificate levels*” (Smyth 2004, p.7) Transition year is considered to be particularly innovative with its emphasis on “*personal development, self-directed learning and the absence of standardised assessment procedures.*” (Smyth et al 2004, p.1) The programme itself varies from school to school. Each school has the autonomy to chose and design their own timetable and programme in order to cater for the needs of their own students.

With Ireland currently experiencing low numbers of students taking Science second level, particularly in upper second level Physics and Chemistry. (Royal Irish Academy, 2005) The freedom of a curriculum-free year offers teachers/educators the opportunity to contextualize and teach Science in an interesting manner in terms of its role in students’ life and in society.

The Transition Year provides a unique opportunity for teachers to teach Science in an imaginative and relevant way without the confines of a syllabus or an examination. It offers teachers the exciting prospect of changing students’ views of Science through teaching interesting and relevant material. The Transition year sampling of different subjects offers an opportunity for students to make informed decisions about their subject choice at Senior cycle. This unique year should be used as a vehicle to promote the uptake of Science. The questions now arise: are Science teachers taking the opportunity of the Transition Year Programme to arouse interest in Science and provide a good foundation for senior cycle Science courses?

A Pilot Study was completed in 2006/07 by Lorraine Lally on ‘An investigation into what is being taught in Transition Year Science’. This project surveyed both TY Science students and teachers in 17 schools in Galway and Limerick.

Results from this pilot study:

- 100% of teachers said that Biology was the most popular subject in their school.
- Few teachers have laboratory time for all of their Science classes during Transition Year.
- Most teachers (61.9%) are teaching from the Leaving Certificate Science syllabi, contrary to the Transition Year guidelines.
- Most (66.7%) were not aware of or using available Transition Year Science resources.

The results from this pilot study indicated a large discrepancy between the Transition Year guidelines and what is actually happening in Transition Year Science classrooms. It was decided to undertake this study on a larger scale, covering the whole country.

Methods

The following research questions guided this project:

- Are teachers following the prescribed guidelines for the TYP?
- Are teachers utilising the opportunity to teach without the constraints of a curriculum in a unique and relevant way, examining areas of science not heretofore encountered?
- What educational techniques/approaches to teaching and learning are TY science teachers using?
- What published resources are TY science teachers using and aware of?
- What are the crucial factors for TY science teachers? i.e. laboratory time, classes per week etc?

The planning of the study involved several stages:

- Examining the pilot study completed by Lally and defining how the project needed to expand;
- Completing a thorough review of the literature on relevant research topics;
- Deciding on the techniques to be used to obtain and analyze the necessary information, including designing teacher questionnaires;
- Selecting and defining the sample to be studied;
- Processing, analyzing, presenting, interpreting the results;
- Drawing interim conclusions from these results and deciding where these conclusions would lead the future research.

This study uses a mixed method approach through questionnaires. While mainly quantitative, there were free response and opinion style questions, allowing for a qualitative approach. This combination of approaches allowed for greater accuracy and reliability of results. Three questionnaires were developed; one main questionnaire and two others based on the University of Limerick's 'TY Science' resources and PharmaChemical Ireland's TY resources. The main questionnaire was developed using some selected questions from the pilot study as a foundation, in order to provide further comparison between the two studies. The remainder of the questionnaire was divided into three sections: section one had questions on factual information about the teacher, their school and teaching methods in TY; section two's purpose was to gather information on attitudes to TY, TY Science and teaching methods in TY Science; the third section's purpose was to discover what resources are being used by teachers in the TY Science classroom and their limitations. All sections of the questionnaire used dichotomous questions, filter/contingency questions, open ended questions and Likert scale statements as discussed in Bell (2005)

Two more questionnaires were developed in addition to the main one. If the respondent in the main questionnaire had used a 'TY Science' resource from the University of Limerick or resources from PharmaChemical Ireland they were directed to complete a further questionnaire on the resource that they had used.

A pilot of the new questionnaires was sent out to ten randomly selected schools from a list of schools offering the Transition Year Programme (TYP), provided by the Department of Education and Science. The purpose of this pilot was to validate the questionnaire, highlight misleading questions and sources of ambiguity. The results of this pilot were used to revise the questionnaires, which were then sent out nationally to all schools offering the TYP (514) in May 2008. All three questionnaires were analysed statistically using the Statistical Package for the Social Sciences (SPSS) Version 16.0.

The limitations of the study were as follows:

- Considering the size of the study (514 schools), the response rate was low, with only 17.1% (N = 88) of the cohort responding. If the number of respondents had been greater it would have greatly increased the reliability of the results. However, a representative sample was still achieved.
- Due to the late approval of ethics the questionnaires were not sent out to teachers until early May. This is usually quite a busy time in schools with summer exams running and State exams being prepared for. This may account for the low response rate. Perhaps if teachers were surveyed at a different time of year the response rate may have been higher.
- Teachers were reminded by phone call to return their questionnaires when the school year began again in September 2008, but unfortunately this did not elicit any more responses.

Results

The Transition Year Programme is compulsory for students in 22.7% of schools offering the programme and teachers are very positive about the Transition Year Programme, with 94.3% believing that the programme is relevant to the world that students live in today and 70.4% of teachers believing that the programme caters for students/learners of all abilities.

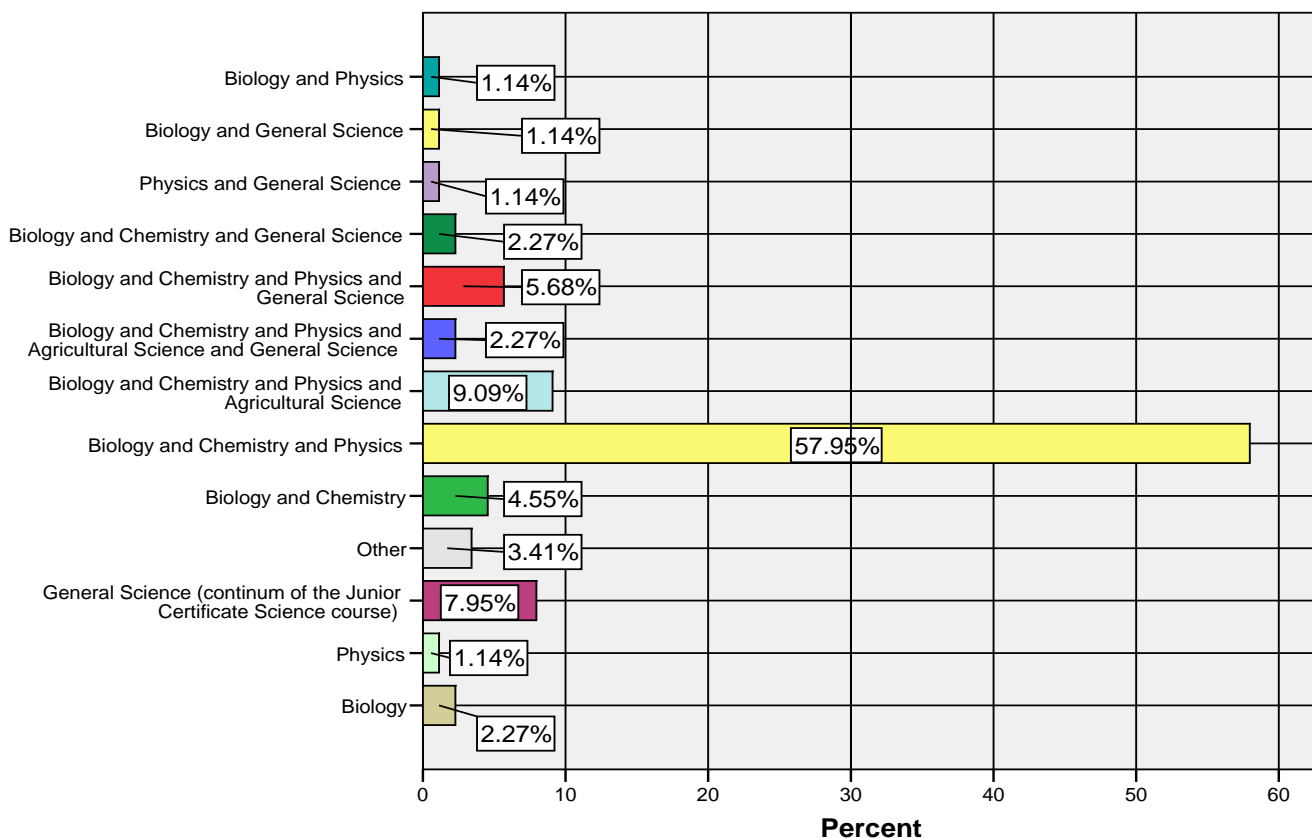


Figure 3. Please indicate what science subjects are taught at your school in the Transition Year (Physics, Chemistry and Biology)? (N = 88)

Unfortunately, as can be seen in Figure 3 only 58.0% of schools offer Physics, Chemistry and Biology at the Transition Year Science level.

Of the subjects offered in the Transition Year, only 62.5% offered Biology, 52.3% offered Physics and 52.3% offered chemistry. Other options such as Horticulture, Applied Maths, Food Safety, Forensics, Agricultural science, Technology, Medical Physics, Earth Science, Waste Management, Engineering, Genetics, Astronomy, Rocket Science, Diseases and Investigative science were offered.

A few teachers noted that pupils could choose what science subject to take but nearly all students chose Biology. Other schools offered either two of Physics, Chemistry or Biology depending which teachers were timetabled.

One school noted that this year they were only looking at Physics.

Only 11.4% of teachers include practical work in every Transition Year Science class and only 42% of teachers include it in every double. This is very disappointing, as practical work is an integral part of science and the curriculum free year allows a wonderful opportunity for hands-on practical work, especially as time in the laboratory is not a critical factor for teachers.

Unsurprisingly, Biology is the most popular science subject in schools with, 85.2% teachers stating this.

An important result from this study, which can be seen in Table 2 below, is that 62.5% of teachers are teaching from the Leaving Certificate Science syllabi in their Transition Year science classes; this is in direct contradiction with the Transition Year Guidelines. (Department of Education and Science 1993)

Table 2. Percentage of teachers teaching from Leaving Certificate Science syllabi in the Transition Year

Subject	Percentage
Physics	27.9
Chemistry	32.5
Biology	43.0
Not teaching from Leaving Certificate Science syllabi	31.4
No response	5.8

Transition Year science classes do incorporate more active learning (72.4%) than science classes in other years and teachers do use more group work (87.5%), ICT (80.7%), DVDs (84.0%) and project work (80.7%), however new or different approaches such as team teaching approaches (30.9%), discussion, debate, oral presentations, interview and role play (57.9%), personal responsibility in learning/self directed learning (30.9%), and having visiting speakers and seminars (51.1%) are under utilised. Transition Year students being absent from their science classes due to other school activities is a major issue for teachers (78.3%) as is the availability of resources (48.8%).

As can be seen in Table 3, the most well known resources are the University of Limericks 'TY Science' modules, the National Council for Curriculum and Assessment (NCCA) School Units and PharmaChemical Ireland's Transition Year Science Modules. This is clearly reflected in teacher's usage of the modules with 42.0% of teachers having used the University of Limerick's 'TY Science' Resources and 18.2% having used Transition Year Science resources produced by PharmaChemical Ireland.

Table 3. Popularity of Transition Year Science Resources

Name	Author/Producer	% who have heard of this resource
University of Limerick 'TY Science' Modules	Various/Dr. Peter E. Childs	56.8%
PharmaChemical Ireland's Transition Year Science Modules	Various/Mark Glynn	33%
NCCA Schools Networks Transition Year Units	Various	55.1%

Only 42% of teachers are using published resources in their Transition Year Science classroom, a number which is considered significant $p < 0.05$, when compared to the number of teachers teaching from the Leaving Certificate Science Syllabi (62.5%)

Conclusions and Implications

In order to come to conclusions within this study, it is important to return and look at the results in the context of the original research questions.

Are teachers are following the prescribed guidelines for the TYP?

Teachers are not following the prescribed guidelines for teaching science in the Transition Year. Over two thirds of them are teaching from the Leaving Certificate Science syllabi and many who do so believe that it is necessary. This agrees with the finding in the pilot study by Lally (2007). Teachers are clearly not following the prescribed guidelines for the Transition Year Programme. Specifically, the Transition Year Guidelines state that, “*A Transition Year programme is NOT part of the Leaving Certificate programme, and should NOT be seen as an opportunity for spending three years rather than two studying Leaving Certificate material.*” (ScoilNet, 1999) Many teachers appear to view the Transition Year as an extra year in the Leaving Certificate cycle. Most teachers believed that their reasons for teaching from the Leaving Certificate Science syllabi were sound and that it opened pupils’ eyes to what science was like at Senior Cycle and how difficult it was.

Teachers who believe that science is a difficult subject may be passing on these prejudices to their students at Transition Year level. If a science programme, other than the one on the Leaving Certificate courses, were taught in a relevant and exciting way, could it change students’ perceptions of Science?

Are teachers utilizing the opportunity to teach without the constraints of a curriculum in a unique and relevant way, examining areas of Science not heretofore encountered?

Most teachers use Transition Year to bring their students on educational class trips, showing that students are being exposed to some new areas of Science. Teachers are incorporating many of the recommended teaching techniques in Transition Year. (ScoilNet, 1999)

Yet not all of these techniques are being utilised. The more common techniques such as group work, activity based learning, use of computers, showing DVDs, project work and research all feature highly on teachers list of commonly used teaching techniques. Despite this, the more unfamiliar techniques are rarely used. Team teaching, personal responsibility/self directed learning, visiting speakers, debate, interview, discussion, oral presentations and role play are all rarely used. It is not enormously difficult to include group work and activity-based learning in Science as most experiments are active and done in pairs. It once again suggests that in the Science classroom in Transition Year teachers are reverting to what is familiar and are not examining science in a new, exciting and relevant manner.

What educational techniques/approaches to teaching and learning are TY science teachers using?

Teachers do not use new or different teaching techniques in the Transition Year, with Transition Year Science teachers incorporate more active learning than in their other classes (72.4%). Teachers are using a very limited range of teaching techniques, and in doing so are not following the recommended guidelines for the teaching of Transition Year Science. The most commonly used techniques seem to be the ones that teachers are the most familiar with, such as Activity based learning, group work, and showing DVDs to reinforce material being taught.

What published resources are TY science teachers are using and what are they aware of?

Teachers are not aware of many published resources for Transition Year. When teachers were presented with a list of published resources commonly on offer, many had not used, or even heard of most of them. However, 42% of teachers are using published resources, and a few use ones of their own creations.

What are the crucial factors for TY science teachers i.e. laboratory time, classes per week etc?

The crucial factors for teachers are not what were originally expected. Based on the study by Lally (2007), it was originally expected that the crucial factors for teachers would be lack of laboratory time.

Clearly this is not the case. Teachers do however feel the pressure of time constraints, both on their own time and on the pupils'. Student absenteeism due to other school activities appears to eat into already limited class time in Science. This raises the question: is this the case for all classes in Transition Year or is just Science affected?

Future Work

In order to answer the further questions that have been thrown up by this study further work needs to be undertaken. This work will be completed in two separate phases, these phases will run simultaneously.

Second Phase:

- A more detailed examination of the resources available for Transition Year Science and their use by teachers.
- Student attitudes and perceptions to Transition Year and Transition Year science will be examined, through survey, in order to investigate the effects on students' attitudes to science and uptake. Does Transition Year have any effect on subject choice for Senior Cycle?
- Teacher attitudes, opinions and uses of Transition Year Science will be re-evaluated through survey (random selection of 50 schools to avoid sample bias).

Third Phase:

This phase will examine schools' management and organisation of the Transition Year programme and the management and organisation of science within the Transition Year Programme. This will be achieved through the use of case studies of selected schools and teacher interviews. It is clear from these preliminary results that the opportunity to use the Transition Year to teach Science in an imaginative way has largely been wasted in Irish Schools.

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TENSIONS THAT STUDENTS FACE IN THE LEGO-ENGINEERING, DESIGN-BASED SIMPLE MACHINES MODULE

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Abstract

Despite the lack of design-based curriculum for elementary school students and teachers' low self-efficacy in regard in teaching design, there appears to be a strong demand for engineering (design) education in schools. We believe that deepening science learning and increasing integration of engineering education in elementary levels can be accomplished concurrently with using engineering based curricular modules in elementary science classrooms. This study is a part of the NSF funded, Transforming Elementary Science Learning through LEGO Engineering Design (TESLED) project. In this study, LEGOs, which are technological as well as mechanical, are introduced as a new instructional tool. The overall purpose of the study is to develop, implement, and evaluate new curriculum units designed to renovate elementary science learning by using LEGO engineering design. The LEGO engineering-based simple machines module, which was developed for 5th grades by our research team, was piloted in an urban school in a big city in the Northeastern region of the US. We found several tensions or contradictions as a part of our analysis. These included (1) Content knowledge vs. process of science, (2) Aesthetics vs. Function, and (3) Individual vs. Group.

Introduction

Increasing technology oriented daily life practices expands the importance of science and technology education starting with the elementary grades. Standardized test results mirror the need for deeper understanding in elementary science education. In the 2005 National Assessment for Educational Progress (NAEP) test, 73% of fourth graders in the U.S. scored under proficient level in science (National Center for Education Statistics, 2006).

Not only improvements in science education, but also integration of engineering education are needed in elementary classrooms. Engaging students in design learning opportunities has been found to be an effective way of helping students understand how to manipulate and model data (Lehrer & Romberg, 1992), which, in turn, support students in developing domain specific knowledge. Unfortunately, in elementary school settings, design-oriented tasks are often not implemented for various reasons. These reasons include lack of design-based curriculum for elementary school students and teachers' low self-efficacy in teaching with design-oriented tasks (National Research Council, 1996). Despite these challenges, there appears to be a strong demand for engineering (design) education in schools.

The American Society for Engineering Education (ASEE) conducted a survey on K-12 teachers examining the need for engineering education in schools (Douglas, Iversen, & Kalyandurg, 2004). 90.3 % of teachers agreed that 'understanding more about engineering can help them become a better teacher', and 84 % agreed that 'their students would be interested in learning engineering'. Even with this strong demand for engineering education in K-12 schools, students lack of engineering awareness. A recent study reported that less than 15% of 504 elementary students in one Massachusetts district, correctly identified 'creating ways to clean water' as something that engineers

do, while over 70% incorrectly chose ‘drive machines’ as a special engineering task (Cunningham, Lachapelle, & Lindgren-Streicher, 2005).

This study that is a part of the NSF funded, Transforming Elementary Science Learning through LEGO Engineering Design (TESLED) project. In this study, LEGOs, which are technological as well as mechanical, are introduced as a new instructional tool. This tool is not foreign for most students since many of them had played with LEGOs when they were younger. The overall purpose of the study is to develop, implement, and evaluate new curriculum units designed to renovate elementary science learning by using LEGO engineering design. The driving questions for our work have been:

1. Is the engineering design-based curricular module on simple machines effective in teaching students?
2. What are the tensions/contradictions in the process of engineering-design based instruction?

Background

Activity theory was used as both the theoretical lens and tool of analysis in this study. The relationship of the participant and the object as it was mediated by the components of the activity system were examined. These components were (a) the tools, which were both human and technology based; (b) the classroom micro cultures which demonstrated the emergent norms; (c) the division of labor as indicated by the group dynamics and the student-teacher interactions; and (d) the rules which governed the activity, which, in this case, were the engineering design principles. This study was analyzed by looking at a sequence of events or ‘nested activities’ using the visualization developed by Engstrom in 1999 shown in Figure 1 below.

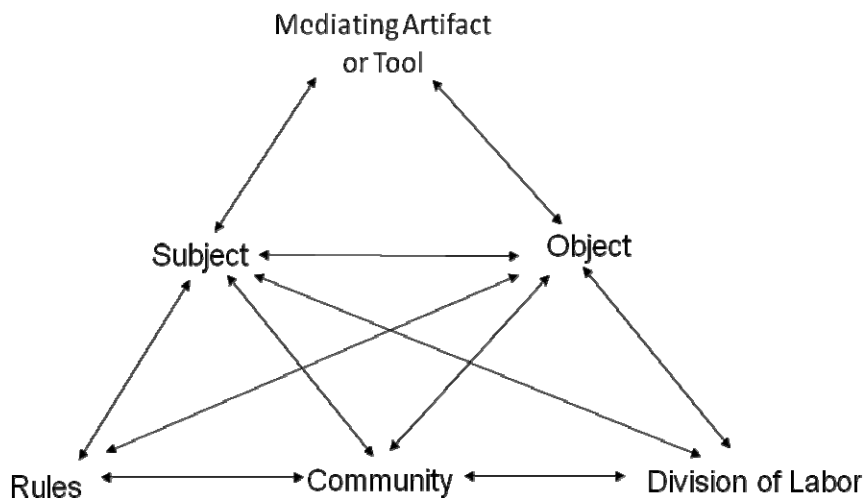


Figure 1. Sequence of events or ‘nested activities’ in Activity Theory (Engeström, 1999).

This diagram demonstrates that activity systems can be seen as complex formations in which equilibrium or balance is the exception; tensions, disturbances and local interventions are the rule that drive the transformation or appropriation (Barab, Barnett, Yamagata-Lynch, Squire, and Keating, 2002). When this schematic is applied to the Lego activity system, the model is transformed to illustrate the activity system shown in Figure 2 below.

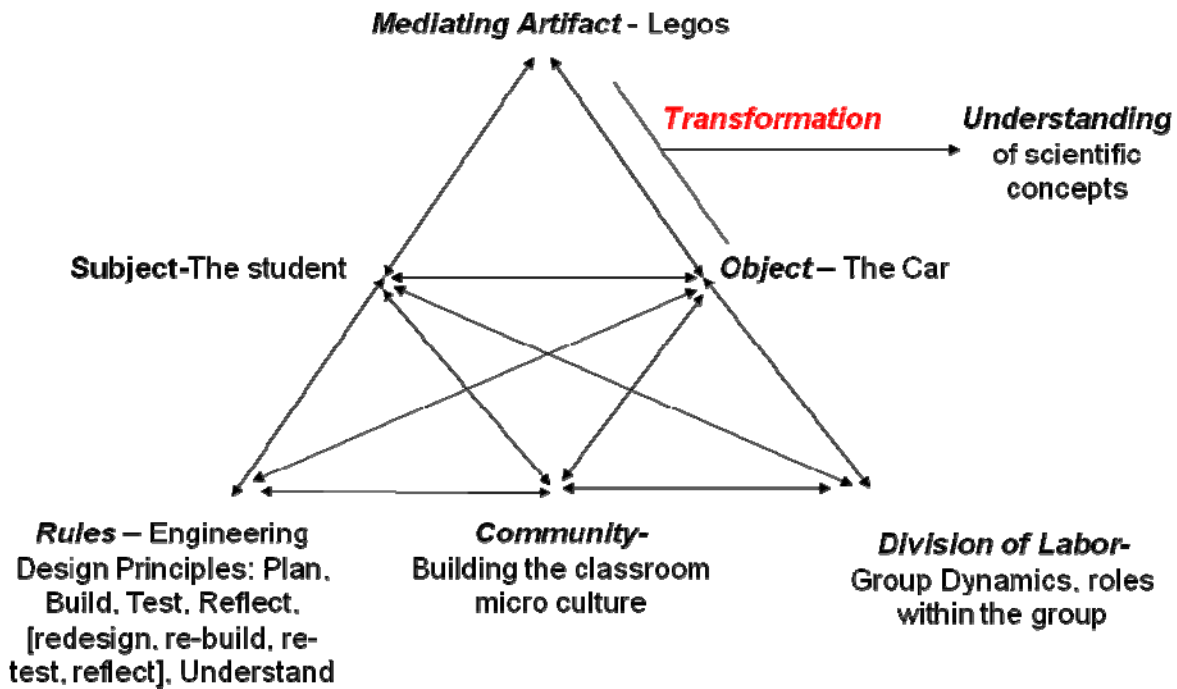


Figure 2. Diagram of a Lego activity system.

In the Lego Activity System students are the subjects. Also, the teacher could be considered among subjects if the teacher is active in the system. Basically, the specific activity determines who the subjects are. If it is a group activity and the activity takes place among a group of students, then the subject is students that have a role in the activity. The mediating artifact or tool in a Lego Activity System is Legos. The object that students need to attain is to make a complex machine with specific features. The rules that the students need to consider are engineering design principles. The classroom micro culture defines the community, and group dynamics and roles within groups define division of labor aspects of the activity system.

Methods

A mixed-methods approach is going to be used to answer the research questions. We see numerous advantages of using a mixed-method approach. These include having different perspectives with each method, being able to gather more in-depth information, and being able to ensure reliability. Lincoln and Guba (1986) suggested triangulation as one of the ways of increasing the reliability of researcher interpretations. We triangulated data through multiple sources, including direct observations, tests, interviews, and student laboratory reports. The driving questions for this work have been:

1. Is the engineering design-based curricular module on simple machines effective in teaching students?
2. What are the tensions/contradictions in the process of engineering-design based instruction?

Context of the Study

During the 2008-2009 academic year, we piloted a portion of the TESLED work in an urban school in a big city in the Northeastern region of the US. The school has demographics of 33.3% Black, 64.2% Hispanic, 1.1% White, 0.8% Asian, and 0.6% Native American. Also the school has 47.9% Regular Education, 22.3% Special Education, and 29.7% Bilingual Education students. The LEGO engineering-based simple machines module, which was developed for 5th grades by our research team, was piloted in two and a half weeks of the fall semester of 2008/2009 academic year. The two fifth grade classrooms in the school had 17 and 16 students with about an equal boy/girl ratio. One of the fifth grade teachers taught the simple machines module to both of the classes. One of the

researchers observed and videotaped four of the lessons. The pre-test and the pre-interviews were conducted right before the instruction, and the post test and the post interviews were conducted a week after the instruction.

In answering the research questions we have been using mixed-method approaches. Data collection methods include pre- and post-tests, pre- and post-interviews, student lab reports, and laboratory observations. We analyzed pre- and post- tests by using the SPSS software. In terms of analyzing the student interactions we watched the video tapes and broke the student discussion down into interactive episodes. These video episodes were then grouped and analyzed holistically with the goal of identification of particular tensions or contradictions that either supported or inhibited learning.

Results

For the purposes of this paper we are focusing our attention on student outcomes. The written test included five open ended and six multiple choice questions about the simple machines that students learned in the module. In eleven test items, students did significantly better on eight of them after the design-based instruction (see Figure 3). From the pre and post test scores, we have found that students who participated in the study showed significant growth in content understanding. As seen in Figure 3, students’ mean scores in all test items are increased after instruction. In eleven test items, students did significantly better on eight of them.

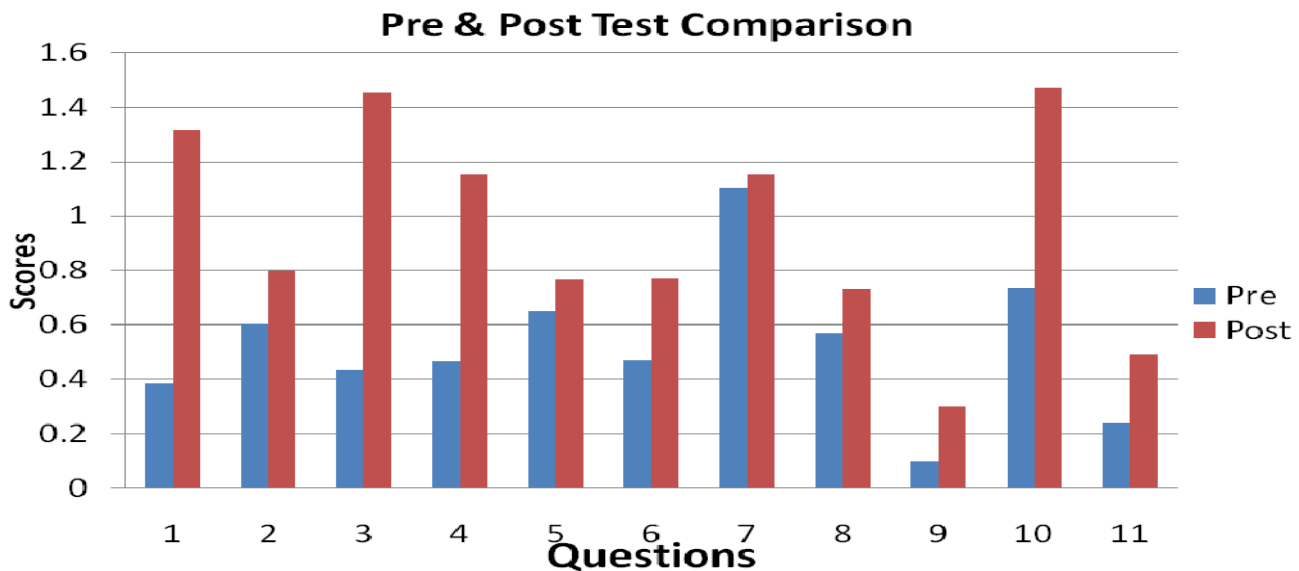


Figure 3. Students’ mean scores on pre and post tests.

Systemic tension 1 – Content knowledge vs. Process of science/engineering

The first tension that became apparent to us is the tension between students’ previous content knowledge versus process of science/engineering. The scientific/engineering process requires to plan before building anything; however, it is observed that some groups started building right away without doing any planning while others planned before to start building. We believe that one of the main reasons for skipping the planning stage and to start building is students’ previous content knowledge on the subject. Because they have previous conceptions on the content they skip planning and start building. Based on their previous conceptions they plan as they build.

Systemic tension 2 –Aesthetics vs. Function

The final challenge of the module is to build a complex machine that can move the Lego-man six inches up and eighteen inches across. The complex machine must include at least three simple machines in it. The second tension that appeared to emerge was that of aesthetics versus functionality of the machine. For example, one of the students in the class focused on building a fancy car (as a wheel and axle) rather than two other simple machines

that his group was supposed to use. While he was building his fancy car, his partner was trying to build other simple machines that they need in the final challenge. When the researcher asked this student what he was planning, he replied that he is planning to build a big car.

From this conversation it is easy to see that the student was clearly unfocused from the task at hand; by focusing on the aesthetics, the student forgot about the challenge of making the machine functional. This brings up the tension of skipping the planning stage to go straight to the building phase. Creating a cross activity tension between the students and the building the machine is shown in Figure 4.

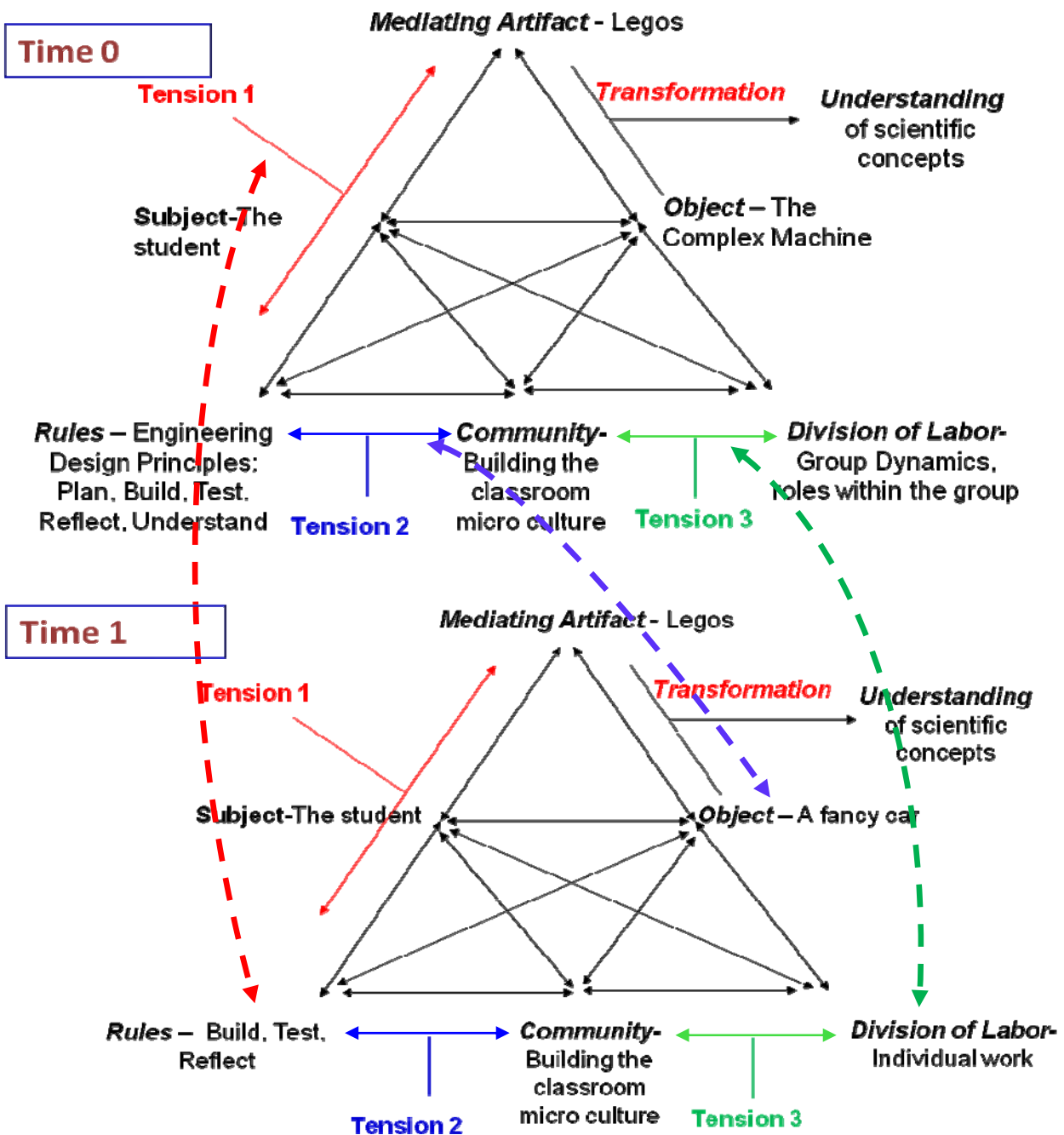


Figure 4. Diagram of the tensions and their possible changes in the Lego activity system.

Additionally, it brings up the idea of being too immersed in the system versus being a deliberate designer. In this instance, the teacher, as the mediator, helps to re-direct the student back to the original object outcome, building a functional machine.

Systemic tension 3 – Group vs. Individual.

The third tension that emerged was the interest the groups had in other activity systems which existed within the class. During the Lego-engineering design challenge activities, students worked in pairs as groups. Group members moved between the groups for various reasons. This had both positive and negative outcomes. From the positive perspective, when the students interacted with other activity sets in the classroom, they were able to bring information, ideas, and sometimes Lego parts back to their own activity set. While this often helped them to continue on within their own nested activity group, more often it resulted in the group members losing focus on what they were supposed to be doing.

The result of this crossover between activity sets is that additional tensions are imposed upon the overarching tensions which already existed. Figure 4 shows an example of cross activity set interactions. Figure 4 illustrates a Lego activity system and possible changes in its elements in time. These changes are due to the tensions. Dotted lines show the tensions and their cross activity results in time. For example, the first systemic tension may cause a change in the rules of the activity system. When the focus of the subject is content knowledge rather than the process of science, some of the engineering principles that constitute the rules of the activity system may be omitted. Similarly, when the subject focuses on aesthetics rather than functionality, the object may transform to building a fancy car rather than building a functional complex machine. Lastly, when the subjects choose to work individually, the division of labor may be reduced to individual work. The tensions that we identified in the study have a potential to transform the activity system to a different activity system in time.

Conclusions and Implications

Activity systems provide opportunity for learning to occur within these systems. Learning should no longer be mere rote memorization of facts, figures and processes. However, it is important that support is given to the student actions in their own construction of knowledge as they emerge from these activity/learning systems. This activity emphasizes the “situated nature of cognition and meaning” (Barab et al, 2002, Barab & Plucker, 2002) suggesting a “reformulation of learning in which practice is not conceived of as independent of learning and in which meaning is not conceived of as separate from practices and contexts in which they are developed” (Barab et al, 2002, Lave & Wenger, 1991).

The results of the study suggest that engineering-design based curricular modules have a potential for deepening science learning as well as increasing integration of engineering education in elementary levels. With this study, we hope to advance the knowledge within the educational research community on theory, design and practice in the emerging field of elementary-level engineering education, which we believe can improve elementary-level science learning.

Acknowledgements

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CREATIONIST CONCEPTIONS OF PRIMARY AND SECONDARY SCHOOL TEACHERS IN NINETEEN COUNTRIES

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Abstract

Our work is the first international comparison of teachers' conceptions on Evolution / Creation, using several questions on precise and large samples to identify the importance of creationist ideas in the context of their national, religious, economic, cultural and political backgrounds. This research concerns 19 countries: 13 in Europe, 5 in Africa and one in Middle East: 7050 teachers filled out a questionnaire including several questions on Evolution vs. Creation. Half of them are in-service teachers, the other being at the last year of University before teaching. They are teaching in Primary Schools as well as in Secondary Schools (Biology, or Language). The percentages of teachers' radical creationist conceptions differ more from one country to another (from 2% to 90%) than among religions inside each country. There are some, but not so important, differences between Biology teachers and other teachers. The teachers' conceptions also differ with the level of teacher training: more they are instructed (in any matter), more they are evolutionist.

Introduction

Although schools are the core targets of the anti-evolutionist offensive (IAP, 2006), relatively few studies have assessed teachers' conceptions of the issue and not one has focused on an international comparison of them. Prior to our project, there had been few surveys (Miller, 2006 ; Special Eurobarometer, 2005) which assessed the spread of creationist and / or evolutionist ideas among adults. The most documented one to our knowledge (Miller, 2006) compiled several polls from 34 countries (of which 32 were in Europe, including Turkey; plus Japan and United States). Its results showed that the U.S. and Turkey were the most creationist countries. A recent work

(Hameed, 2008) published data gathered from only one question in six Muslim countries, others than those analysed in the present work, showing a high reject (61 to 73%) of Evolution in five of them, but a less important reject (27%) in Kazakhstan.

We distinguished anti-evolutionist conceptions (radical creationism) from conceptions which were both creationist and evolutionist. In his famous paper *"Nothing in biology makes sense except in the light of evolution"*, Dobzhansky (1973) wrote *"I am a creationist and an evolutionist. Evolution is God's, or Nature's, method of Creation"*. When teachers have this kind of "creationist-evolutionist conception" they can teach biological evolution at school without problem.

Rationale

What are, in the 19 countries chosen by their diversity (inside Europe, and also outside) the teachers' conceptions on biological Evolution / Creation ? Is it possible, using several questions on precise and large samples, to identify the importance of their possible creationist ideas in the context of their national, religious, economic, cultural and political backgrounds? Our work is the first international comparison of this size analysing the teachers' conceptions related to this topic. His first results were already published (Clément & Quessada, 2008, 2009).

Methods

This research has been done in the context of the research project BIOHEAD-Citizen in 19 countries in Europe, Africa and the Middle East (Biohead-Citizen, 2004-2008). The 19 countries were selected for their diversity of economic development and socio-cultural contexts, especially regarding religion (table 1). Between 2006 and 2007, a total of 7,050 teachers anonymously filled out a questionnaire which included fifteen questions related to Evolution (six of which were related to creationism) as well as questions regarding personal information (such as age, gender, and socio-cultural information including political and religious beliefs). The sample was a balanced set of in-service teachers and pre-service teachers (i.e. adults in their last year of teacher training), in both primary and secondary schools, who taught biology or the national language. The table 1 presents the total sampling of each country, with more precisions regarding the declared teachers' religions. The questionnaire has been built during the two first years of the project (2004-6), then tested (pilot test and other tests), translated, validated and finally improved (Clément & Carvalho, 2007). The data are analysed by classical statistical tests as well as by multivariate analyses (software "R") (Munoz & Clément, 2007 ; Munoz et al., 2009).

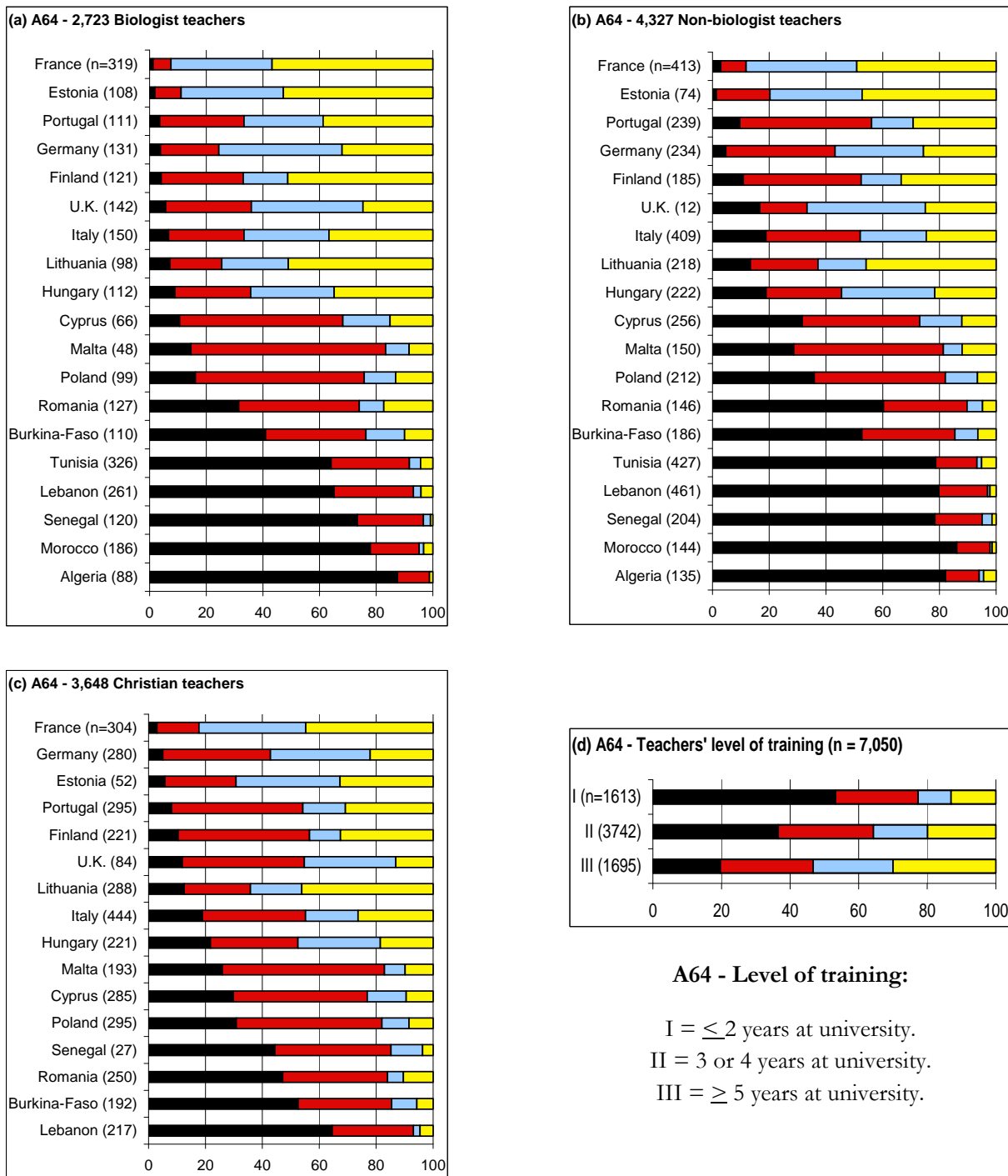
Table 1. Presentation of the samples for the 19 countries - "biologists" are the in-service and pre-service biology teachers + other teachers having a training in biology at University (some Primary school teachers). - *Other* = mainly no answer to the question + all the other religions.

	Country	Total	including biologists	% Atheist. Agnostic	% Catholic	% Protestant	% Orthodox	% Muslim	% Other
BF	Burkina Faso	296	110	2,4	45,6	18,6	0,0	24,7	8,8
CY	Cyprus	322	66	4,0	9,0	1,2	77,3	0,0	8,4
DE	Germany	365	131	13,4	44,7	31,8	0,0	0,3	9,9
DZ	Algeria	223	88	1,3	0,0	0,0	0,0	91,9	6,7
EE	Estonia	182	108	43,4	7,7	14,8	2,2	0,5	31,3
FI	Finland	306	121	15,0	1,0	66,3	2,9	0,0	14,7
FR	France	732	319	50,5	38,1	1,9	0,3	1,5	7,7
GB	Great Britain	154	142	33,1	11,0	33,8	0,6	0,0	21,4
HU	Hungary	334	112	15,3	46,4	16,2	0,0	0,0	22,2
IT	Italy	559	150	12,3	78,7	0,5	0,0	0,0	8,4
LB	Lebanon	722	278	0,4	21,1	0,4	8,3	65,0	4,8
LT	Lithuania	316	98	4,1	89,9	0,6	0,3	0,0	5,1
MA	Morocco	330	186	0,6	0,0	0,0	0,0	97,3	2,1
MT	Malta	198	48	0,5	96,5	1,0	0,0	0,0	2,0
PL	Poland	311	99	1,9	94,2	0,6	0,0	0,0	3,2
PT	Portugal	350	111	9,4	76,3	7,4	0,0	0,0	6,9
RO	Romania	273	127	7,3	8,1	7,0	71,1	0,0	6,6
SN	Senegal	324	120	0,9	8,3	0,0	0,0	89,2	1,5
TN	Tunisia	753	326	1,9	0,0	0,0	0,0	96,0	2,1
Total		7 050	2 723	11,8	35,1	8,3	7,4	29,6	7,8

Results

1 - National context, belief in God and GDP

In several countries, most of the teachers display creationist conceptions. There is a very large contrast across countries: for instance, for a question related to the origin of life, from 2% to 90% of radical creationist conceptions, Figure 1). There is a very significant correlation between such conceptions, belief in God and religion practice and also a strong inverse correlation with the GDP (Gross Domestic Product) per person. The GDP/person (Gross Domestic Product / person) is correlated with the degree of belief in God ($r = -0.69$, p -value = 0.001) and of religious practice ($r = -0.76$, p -value = 0.0001) and also with the teachers' creationist conceptions ($r = -0.73$, p -value = 0.0004).



A64 - Level of training:

- I = ≤ 2 years at university.
- II = 3 or 4 years at university.
- III = ≥ 5 years at university.

A64 - Which of the following four statements do you agree with the most? (tick only ONE answer)

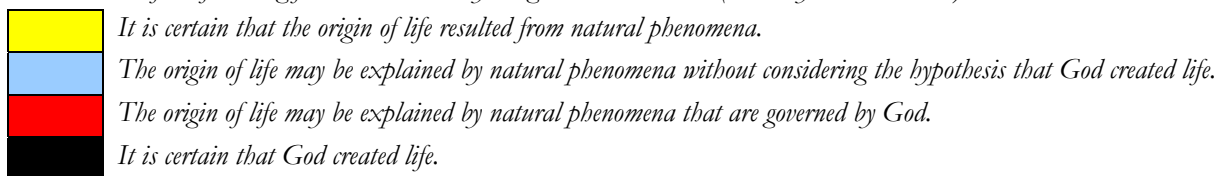


Figure 1. Answers to question A64 (“origin of life”) in the 19 countries (7,050 teachers)

A large proportion of creationist teachers also acknowledge evolutionary processes (for example, in the Figure 1: item 3: "*The origin of life may be explained by natural phenomena that are governed by God*"). The percentage of radical creationist conceptions related to the origins of mankind is similar to those of the origins of life, with the same, marked differences between countries. The answers to the four other questions related to creationism are significantly correlated with those from the questions on origins of life (figure 1) and of humankind.

2 - No (or few) difference between religions inside each country

The percentage of teachers' creationist conceptions differs more between countries than between religions within the same country. Among the 3,648 Christian teachers, the percentage of evolutionists varies greatly: from 97% in France to 36% in Lebanon (Figure 1c).

More precisely, in each country, there is no significant difference between conceptions of Catholic and Protestant teachers (Chi² test).

In our samples, Orthodox teachers were dominant in Cyprus (77%) and Romania (71%), and less present in Lebanon (8%) (Table 1). Their answers about the origin of life are not significantly different from those of Catholic teachers ($p > 0.05$, Chi² test) within each of these three countries.

In Burkina Faso and Lebanon, there were Muslim and Christian teachers (Table 1). In Burkina Faso, 40% of the Muslim teachers are radical creationists compared to 53% of Christian teachers, whereas the trend is reversed in Lebanon where the proportion of radical creationist answers is higher among Muslim as opposed to Christian teachers (80% compared to 65%). In summary, the proportions of creationist and evolutionist conceptions do not vary, or vary scarcely, within the same country according to the religion of the teachers, but when one takes into account teachers who share the same religion, they vary very strongly from one country to another. This conclusion does not concern agnostic or atheist teachers who are evolutionist regardless of their country.

3 - The influence of university teacher training

A Chi² test (with Bonferroni's correction) shows that biologists are more evolutionist than non-biologists. As explained in the legend of the table 1, "biologists" are the in-service and pre-service biology teachers + other teachers having a training in biology at University (some Primary school teachers). Nevertheless, the figures 1a & 1b show that the difference between biologist and other teachers is not so important; the difference is significant in only 9 countries among the 19.

We also found that the greater length of time a teacher studied at university, the more evolutionist he or she is, regardless of the subject he or she teaches in primary or secondary schools. Of the total sample of 7,050 teachers, the proportion of radical creationists (Figure 1d) is 20% after 5 years or more of university, 37% after 3 or 4 years, and 53% after 2 years or less. These differences are the same for the 5 other questions related to creationism. Since this effect may be a bias resulting from the lower level of teacher qualification in less developed countries, we tested the variation in conceptions across number of years spent at university when the variation across countries and religions was controlled. A randomization test confirmed the effect of the length of teacher training at university (p -value < 0.001).

Conclusions and Implications

We just summarized our results here, answering to the research questions: there are very important differences of teachers' conceptions on Evolution / Creation from one country to an other. And we identified, using several questions on precise and large samples, strong correlations between creationist ideas and some other features than their nationality: degree of believing in God and of religious practice (but very few with other political of social. These results could be discussed more precisely country by country. We just wish to conclude here that they offer encouragement to teach Evolution in schools in a more effective way, and, more generally speaking, the longer is the period of teacher training at university, the greater the acceptance of evolutionist ideas.

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EFFECTS OF TASK PROFILES ON STUDENTS PERFORMANCE IN PISA 2003

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Abstract

This study was initiated due to results from the Programme for International Student Assessment (PISA) 2003. Besides the subject-specific competencies mathematics, reading and science also cross-curricular problem solving competence has been assessed in PISA 2003. Results from PISA 2003 show on the one hand a high correlation between cross-curricular problem solving and scientific literacy ($r = .80$). On the other hand some countries, among others Germany, showed a considerable difference between students' mean performance in problem solving and science in favor of problem solving (Leutner et al., 2004). This difference might be an indicator for students' cognitive potentials which are not being used sufficiently for developing scientific literacy. Taking a closer look at the tasks that were used to measure these competencies reveals differences in the way they are constructed and structured. As already proven in many empirical studies, certain task characteristics can have an effect on students' performance (e.g. for answering-format: Martinez, 1999). The aim of this research project is to analyze the differences of science- and problem solving-tasks in order to gain possible explanations for the discrepancy between problem solving and science performance among students in Germany.

Theoretical Background

Problem solving is often seen as a "key competence" in modern society (Funke, 2003). Therefore PISA has analyzed cross-curricular problem solving competence beside subject-specific competencies in terms of literacy in the domains of mathematics, reading and science in 2003 for once. In the international comparison a you can find a relatively high correlation can be found between science and problem solving ($r = .80$; Leutner et al., 2004). On the other hand there is a decisive result for the German students: They perform significantly better in problem solving than the international average (513 points on the international scale with a mean of 500 and a standard deviation of 100 among OECD countries). In science they are only in the international average (502 points). This discrepancy is especially pronounced in the low performing end of the achievement scale.

Because of this result there is the hypothesis that German students do have cognitive disposal, as they show in problem solving, but they cannot make good use of it in the field of science (Leutner et al., 2006).

When analyzing the results of the PISA-study, you also have to scrutinize the tasks that were used to measure these competencies. In the PISA-framework different features of the task construction process are mentioned (e.g.: processes or situations; OECD, 2003). Both for science and problem solving similarities but also differences can be found in the elaboration of the features. Many empirical studies have shown that different forms of characteristics have an effect on the cognitive demand of a certain task (e.g. for answering format: Martinez, 1999; for text structure: Granzer et al., 2009). Furthermore the context of a task can have an effect on students' motivation to work with the task (e.g. Cordova & Lepper, 1996).

In consequence there were two research questions to be answered:

What are the specific characteristics of science- and problem solving-tasks in PISA 2003? By gathering these specific characteristics it is possible to draw task profiles for science and problem solving.

In order to explain the discrepancy of the results of German students it has to be explored if the task difficulty is influenced by the task profile. According to the theoretical assumptions we expect that modified problem solving tasks will be more difficult than the original PISA problem solving tasks and that modified science tasks will be easier than the original science tasks.

To answer the questions the following three working phases have been planed:

Phase a) Task Analysis

In the first step of the study all tasks from science and problem solving in PISA 2003 have been categorized. The analysis took place on item-level ($N_{\text{Science}} = 35$, $N_{\text{Problem Solving}} = 19$). To gather the data of all relevant characteristics appropriately two different instruments have been developed: A category system (following Jordan et al., 2006) and a task-rating sheet (following Langer & Schulz von Thun, 1974). The aim of the category system was to identify task characteristics on a low-inferent level (i.e., low requirements to draw conclusions by the raters). It consists of 26 variables (e.g., given information format, length of sentences, answering format, technical language, etc.) that were scored on nominal, ordinal or metric scales. The purpose of the task-rating sheet was to analyze specific demands and other high-inferent characteristics of the tasks (e.g., types of pre-knowledge, given conditions, context, etc.). It consists of 30 variables. The raters had to assess on a 5-point Likert scale if a certain characteristic was more or less present.

The categories of both instruments were defined by indicators in an extensive manual. During a training phase, raters (students with a scientific background) were taught to the manual which had already been pre-tested and refined several times. The interrater-agreement was calculated for the low inferent (Cohens $\kappa \geq .75$) and the high inferent instrument (Cohens $\kappa \geq .61$), indicating adequate objectivity (Landis & Koch, 1977). After the training, the two instruments were used to work out differences and to describe specific profiles of science and problem solving tasks.

Results Phase a)

The interrater agreement, calculated as Cohen's kappa, shows a result $>.71$ for the low-inferent category system, and for the high-inferent task-rating sheet $>.61$, indicating substantial to almost perfect objectivity (Landis & Koch, 1977). For the comparison of problem solving tasks and science tasks, analysis based on the low-inferent category system revealed following results: (a) Information provided in the task description differs in style and length. A MANOVA was calculated over all categories of the given information and proofs this differences to be significant, $F(1, 54) = 2.48$; $p = .03$; partial $\eta^2 = .27$. Science tasks mostly consist of long introduction texts and only few graphs. In problem solving tasks a lot of charts are given but only short introduction texts. (b) Relevance of the texts differs, $F(1, 53) = 5,41$; $p = .007$; partial $\eta^2 = .18$. In science tasks a lot of irrelevant information is given. In problem solving tasks mostly relevant aspects for working on the tasks are mentioned. (c) The amount of

technical terms used in the tasks differs, $t(52) = 13.31$; $p < .01$; $d = 3.92$. Science tasks contain more subject specific terms. This also leads to a high linguistic complexity in the science tasks in terms of long and complex sentences, $t(52) = 4.66$; $p < .01$; $d = 1.27$, compared to problem solving. (d) In problem solving tasks, the answering format tends to be more diverse, (e.g., filling in charts, diagrams or gaps) whereas science tasks mostly consist of single choice formats. However, Pearson's chi-square test shows no significant difference, $\chi^2 = 2.69$; $p = .10$). In science tasks, short text production format is used more often than in problem solving tasks, $\chi^2 = 5.13$; $p = .02$.

The task-rating sheet has led to following essential results: (a) In problem solving tasks, all relevant conditions are mentioned clearly and are visually emphasized, whereas science tasks generally do not name these at all, $t_{adj}(41) = 8.67$; $p < .01$; $d = 2.67$. (b) The context of the tasks differs, $t_{adj}(26) = 5.23$; $p < .01$; $d = 1.64$. Problem solving tasks are presented in everyday-life situations, whereas science tasks mostly take place in communal and global settings. (c) The tasks differ in terms of required amount and type of knowledge: The science tasks require more subject-specific pre-knowledge, $t_{adj}(50) = 4.28$; $p < .01$; $d = 1.17$, compared to problem solving tasks. In science tasks factual knowledge is more important in order to solve them instead of procedural knowledge, whereas in problem solving tasks, procedural knowledge is more relevant than factual knowledge, $t_{adj}(39) = 7.74$; $p < .01$; $d = 2.25$.

Table 1: Profile of problem solving and science tasks

	Problem solving tasks	Science tasks
Low-inferent level	<ul style="list-style-type: none"> - everyday-life language - diverse answering format - diverse given information (charts, diagrams, numbers) - low complexity of language 	<ul style="list-style-type: none"> - many subject-specific terms - mostly single choice, text production - mostly long introduction texts - a lot of irrelevant information given - long complex sentences
High-inferent level	<ul style="list-style-type: none"> - everyday-life situations - relevant conditions are visually emphasized - procedural knowledge in the foreground 	<ul style="list-style-type: none"> - communal / global settings - not all relevant conditions are mentioned (more pre-knowledge needed) - factual knowledge in the foreground

Phase b) Modification of the tasks

The results from phase a) were used to construct new task types: The specific characteristics of science tasks were transferred on problem solving tasks and vice versa. Only those characteristics were modified which have shown significant differences in phase a). To assure that all the relevant characteristics have been modified in the correct form, the modified tasks were analyzed with both instruments and t-tests were calculated.

Results Phase b)

The task characteristics have been modified significantly in the correct direction. Thereby a new task profile was generated for problem solving and science and we had four different task types: Problem Solving original, Problem Solving modified, Science original and Science modified. For all four task types the number of items was limited to 16 in this step because of the testing load for the students.

Phase c) Testing of new task types

In a last step the new constructed “modified” and the original PISA tasks were tested in three different school forms in North Rhine-Westphalia. The testing-situation was under PISA-similar conditions. Control variables as cognitive ability, scientific pre-knowledge, motivation and interest in science and problem solving were assessed. A questionnaire about students’ background was used from PISA 2003. The modified and original science and problem solving tasks were hand out in 16 booklets organized in a multi-matrix design. Finally the evaluation was performed based on item response theory to find out if the task profile had any effect on students’ performance in the science and problem solving test.

Results Phase c)

647 students took part in the study. The mean age was 15.5 years. The focus of the sample was the low performing end of the achievement scale so we sampled more students from the school form “Hauptschule” (the lowest track of secondary German school system). Central results of the control variables are that the students in the Hauptschule were less motivated to take part in our study compared to the other school forms (Hauptschule compared with the highest track of secondary German school system: $t(380) = 6.86$; $p < .01$; $d = 0.69$; Hauptschule compared with the comprehensive school: $t(475) = 5.13$; $p < .01$; $d = 0.47$). In all school forms the interest in problem solving was significantly higher than in science ($t(646) = 10.47$; $p < .01$; $d = 0.49$). While there is no effect of gender or migration status (country of birth), the language spoken at home plays an important role in the science or problem solving tests: Students who speak a different language than German at home perform significantly worse in both competencies than those who speak mostly German at home ($t(528) = 5.41$; $p < .01$; $d = 0.64$).

In a next step we checked if the two constructs problem solving and science still constitute two separate dimensions in the data. Therefore we calculated a 1-, 2- and 4-dimensional model and compared different parameters to find out which was the best model. The 2-dimensional Model “problem solving versus science” fits best to the data (Reliability: PS = .755, SC = .737; Variance: PS = 1.706, SC = 1.179).

Finally was checked if the modified and original tasks showed an effect on item difficulty within each dimension. The modified problem solving tasks were significantly more difficult than the original tasks ($t(22) = -2.48$; $p = .021$; $d = 1.01$). The modified science tasks were in direction easier than the original tasks ($t(25) = 2.02$; $p = .054$; $d = 0.80$). A possible explanation for this effect concerning science tasks is that the subject-specific pre-knowledge which is needed to solve the task is so important that the profile can not show a significant effect on the performance. This idea can be supported by the data of the pre-knowledge science test which was used in this study: It is the best predictor to explain the science competence (Pearson-Correlation: $r = .54^{**}$) compared to all other control variables.

Conclusions

Analyzing the PISA 2003 science- and problem solving-tasks you can find clear and significant differences concerning many task-characteristics. It is possible to draw specific profiles for science- and problem solving-tasks. These profiles can be used to create new types of tasks. When testing these modified tasks and comparing the results to the results of the original tasks there is a clear influence, especially for problem solving, of the profiles on the task difficulty and thereby on the students’ performance. Regarding to the science tasks a tendency of item difficulty when changing the profile can be found. It seems like that the subject specific pre-knowledge in science is such an important predictor for the scientific competence, so there is no significant effect produced regarding the task profile.

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THE GENETIC DETERMINISM OF HUMAN PERFORMANCES: A COMPARISON BETWEEN TEACHERS' CONCEPTIONS IN FINLAND AND FRANCE

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Abstract

Finland has the best mean sciences scores among the OECD countries while France is in the OECD average (PISA 2006). Nevertheless, when measuring interactions between knowledge and values in teachers' conceptions, the comparison between the two countries shows surprising results. In the context of the European research project Biohead-Citizen, in-service and pre-service teachers filled out a questionnaire including 31 questions related to the genetic determinism of human performances. The samples (732 in France, 306 in Finland) comprised Primary School teachers and Secondary School Biology and Language teachers. The answers to the questions dealing with only scientific knowledge, or with only social values, did not differ with the country. Nevertheless, there are very significant differences for the interactions between knowledge and values mainly related to innatism: for instance, Finnish teachers more agree with the proposition "there are genetic factors in parents that predispose their children to be good in school" (or "good violinists"); or with "It is for biological reasons that women more often than men take care of housekeeping". Our results are analysed with different statistical tests including multivariate analyses. They are then discussed, taking into account the respective content of school textbooks in the two countries.

Introduction: biological and social context

The debate between nature and culture is outdated, both being necessarily in constant interaction (Atlan 1999, Jacquard & Kahn 2001, Kupiec & Sonigo 2001, Lewontin 2003). This interaction between the genome and its environment (called "epigenetics": Morange 2005) is a new paradigm in biology: is it introduced in the school curricula? The European research project BIOHEAD-Citizen (2004-2008) worked on this question, analysing the syllabuses and school textbooks in 19 countries, as well as the teachers' conceptions on this topic.

This is a "question vive" with an important social challenge. The philosopher Canguilhem (1981) defined the explanation of complex social features by only the human genes as an ideology inside Life Sciences. Some psychologists, Keller (2005) in Germany or Dambrun (2007) in France, focused the link between this ideology and intolerant attitudes as sexism or racism. Can we find some link between innatism, sexism and racism in teachers' conceptions?

While Simonneaux (1995), as well as Abou Tayeh & Clément (1999), showed that students' opinions are more difficult to change than their scientific knowledge, Kochkar (2007) showed that some knowledge about the cerebral epigenesis decreases the beliefs in innatism. Can we find a link between teachers' opinions and their scientific knowledge? To answer to this question, we decided to focus our analysis on two countries evaluated as very different by PISA (2006): Finland obtained the best score on the scale of the "scientific literacy" and France obtained a

score just under the OECD average. Concerning the topic "human genetics", and its possible link with ideologies as innatism, sexism or racism, are there differences among the French and Finnish teachers' conceptions?

The innatism is still present in the syllabuses and textbooks of the both countries: Castéra et al (2008) showed a great frequency of the words "genetic program" in French biology textbooks for student 14-16 years old and even more in Finnish biology textbooks for students 16-19 years old. What are the teachers' conceptions on innatism in these two countries?

Rationale: research questions

Are there differences among Finnish and French teachers related to scientific knowledge on human genetics as well as on cerebral epigenesis?

Are there differences among Finnish and French teachers related to ideologies as innatism, sexism or racism?

Are there interactions between scientific knowledge and values of Finnish and French teachers?

Methods

Questionnaire

The questionnaire included 31 questions dealing with the topic "human genetics". Some of them concerned sexist or racist positions, some others the innate determinism of human beings features, and the others the scientific knowledge related to human genetic and cerebral epigenesis. Most of the questions of our questionnaire are built to evaluate possible interaction between K and V (knowledge and values). The values are linked to the sexist ideology vs equality between men and women, to racist ideology when considering a "genetic superiority" of some ethnic groups, or only to the ideology of innatism, as the genetic determinism of human features or performances. The end of the questionnaire was related to personal characteristics of each responder (gender, age, religious or political opinions, etc.). The questionnaire has been built during 2 years, with a pilot test and other processes to select, to translate and to validate the questions (Clément & Carvalho 2007).

Samples

1038 teachers filled in the questionnaire in Finland (306) and in France (732). In each country, six categories of samples were defined in a well-balanced way: in-service teachers of primary schools (InP), in-service teachers of secondary schools in biology (InB) or in language (InL), pre-service teachers of primary (PreP) or secondary schools in biology (PreB) or in language (PreL).

Data analysis

Data from these questionnaires are handled by classical statistical analyses as well as by multivariate analyses (Principal Component Analysis, Between-analysis and Principal Component Analysis with respect to orthogonal Instrumental Variables). The measure of significance was done by Chi² test or by a Monte Carlos test from the between-class analyses (Munoz & Clément 2007; Munoz et al. 2009).

Results

The *Principal Component Analysis* shows strong inter-individuals differences mainly linked to the questions dealing with innatism (component 1) but also to some questions related to scientific knowledge (component 2). The orthogonality of the two components shows their relative independence.

A between-class analysis differentiating the six samples shows that the scientific knowledge differentiates biologists from other teachers in both countries, in the same way for each country.

The between analysis differentiating the two countries shows very clear differences among the teachers of the two countries (figure 1a), differences that are very significant (Monte Carlo test: figure 1b, $p < 0.0001$). In this analysis, the questions differentiating the most the two countries are listed in the table 1.

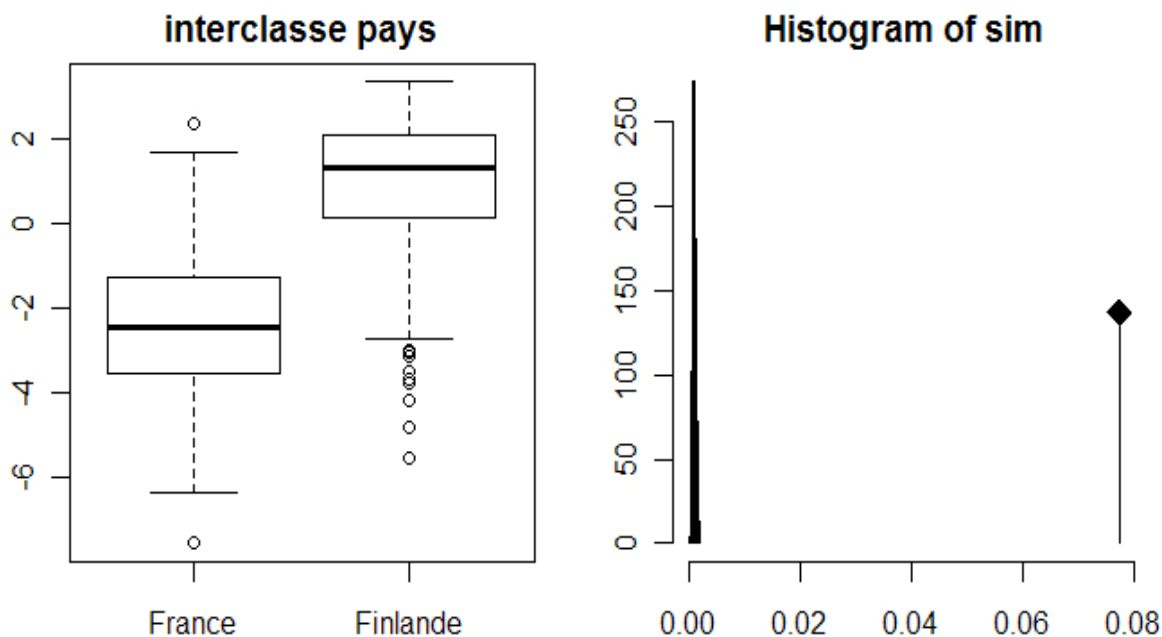


Figure 1. Between analysis differentiating the French teachers' conceptions from the Finnish teachers' conceptions on genetic determinism. (a) - Each box inserts half of the values. The overlapping of the two countries is very reduced. **(b)** - Randomization test (Monte Carlo): the 1000 essays by chance (histogram at left) are very far from the observed value (at right). The difference between the two countries is very significant ($p < 0.0001$).

The question that has the most weight in this "effect country" is the question B10 (figure 2): "*There are genetic factors in parents that predispose their children to be good in school*"? Only 3% of Finnish teachers disagree (while 61% of French teachers do) ; 29% of Finnish teachers agree, 79% agree or rather agree (while only 3% and 18% of French teachers do). The difference between Finland and France is highly significant (Chi² test, p -value $< 2.2e^{-16}$).

The table 1 lists the 13 questions which significantly differentiate the Finnish and French teachers' conceptions. The less but significant difference is dealing with racism: B35 (figure 3): "*Ethnic groups are genetically different and that is why some are superior to others.*" Only 78% of Finnish teachers disagree with this proposition, while 93% of French teachers do. The difference is clearly significant (Chi² test after the Bonferroni's correction: p -value < 0.001).

The answers to 18 questions, from the 31 ones related to the topic of biological detriminism of human features or performances, don't differentiate Finnish from French teachers: the questions focused on only scientific knowledge (except A31: table 1); those related to identical twins and those related to interactions between scientific knowledge and values dealing with sexism or feminism., with the important exception of two of these questions

(listed in the table 1): A38 ("*It is for biological reasons that women more often than men take care of housekeeping*") and A36 ("*Men might be more able to think logically than women, because men might have different brain bilateral symmetry*"). The question A30, dealing with only social values (the number of women in the Parliament), is also significantly differentiating the Finnish and French teachers' conceptions.

Table 1 - List of the 13 questions differentiating the Finnish and French teachers' conceptions (from the between analysis presented in figure 1). For each question, it was a Likert' scale of 4 boxes, from "I agree" to "I don't agree". The figure 2 is illustrating the most important difference (B10) and the figure 3 the less but still significant difference (A35). (...) = The answers to the other 18 questions are not significantly differentiating Finnish and French teachers' conceptions.

D1		
B10	- 0,62	There are genetic factors in parents that predispose their children to be good in school
B20	- 0,59	There are genetic factors in parents that predispose their children to become very good violinists
B4	- 0,57	Human social behaviour is partly directed by genes
B14	- 0,51	There are genetic factors in parents that predispose their children to be aggressive
A38	- 0,50	It is for biological reasons that women more often than men take care of housekeeping
A24	- 0,40	If clones of Mozart could be obtained, they all would be excellent musicians
A3	- 0,40	If clones of Einstein could be obtained, they all would be very intelligent
B11	- 0,36	There are genetic factors in parents that predispose their children to become homosexual
B8	- 0,35	There are genetic factors in parents that predispose their children to become alcoholics
A31	- 0,27	When a couple has already had two girls, the chances that their third child be a boy are higher
A36	- 0,21	Men might be more able to think logically than women, because men might have different brain bilateral symmetry
A35	- 0,17	Ethnic groups are genetically different and that is why some are superior to others
(...)	(...)	
A30	+ 0,20	It is important that there are as many women as men in parliaments

The answers that differentiate the most Finnish from French teachers are linked to innatism. They are mainly dealing with the questions of the genetic factors of parents that predispose their children to be good at school (B10), or very good violinist (B20), or aggressive (B14), or homosexual (B11) or even alcoholic (B8). The Finnish teachers' answers could be a priori interpreted not as innatism, but as telling with the "genetic part" in the double determinism of these features or performances. The same argument could be proposed to interpret Finnish answers to the question B4 (table 1), more agreeing with the proposition: "*Human social behaviour is partly directed by genes*". Nevertheless, the answers to the two questions related to clones (A24 and A3: table 1) clarify the innatism of many Finnish teachers. Considering that clones of Einstein (A3) or of Mozart (A24) would be very intelligent of excellent musicians is considering that these performances have a genetic support.

Finally, we can conclude that Finnish teachers are more innatist than French teachers. Is this innatism linked to other ideologies as sexism or racism? We saw in introduction that this link has been proved in some situations (Keller, 2005 ; Dambrun 2007). Nevertheless: (i) the weight of these questions in the between analysis is clearly less important than the weight of the questions related to innatism (figure 1 and table 1) and (ii) for more questions related to feminist / sexist conceptions, there is no significant difference between the Finnish and French answers. This last point is less surprising considering the feminist reputation of Scandinavian countries, while the sexism of some Finnish teachers, expressed through their answers to 3 questions (A38, A36 and A30) is more surprising. It can be linked with the innatism of these teachers. In these cases, there is a clear interaction between K and V (scientific knowledge and values). This interaction has been found also among the scientists themselves, when the famous Journal Nature published a more ideological than scientific agenda concerning the cerebral lateralisation of men and women (Clément 2001, Vidal 2001).

B10

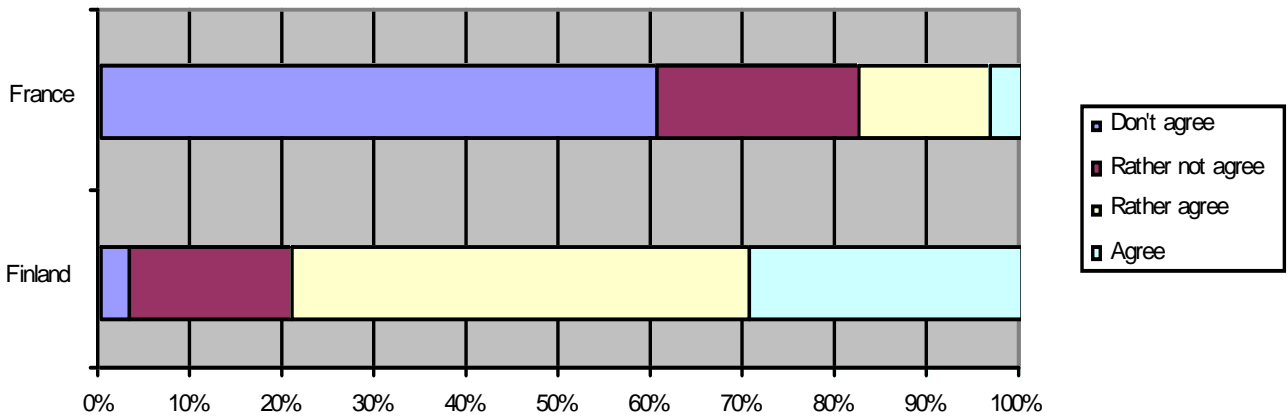


Figure 2. Percentages of French and Finnish teachers' answers to the proposition B10: "There are genetic factors in parents that predispose their children to be good"

A35

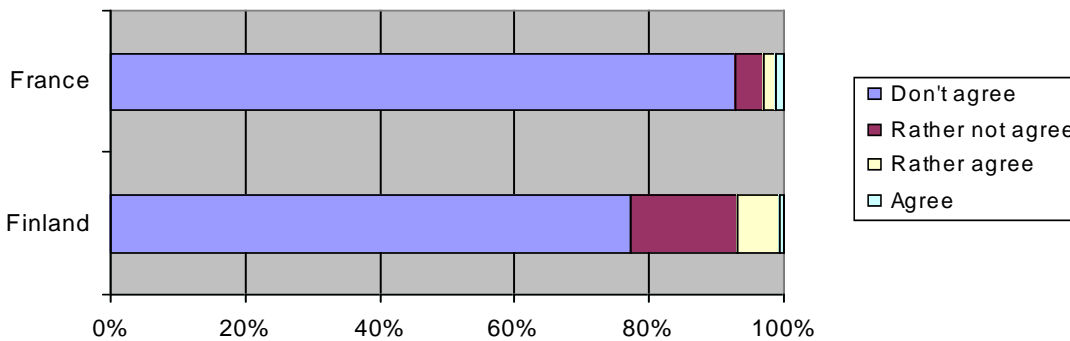


Figure 3. Percentages of French and Finnish teachers' answers to the proposition A35: "Ethnic groups are genetically different and that is why some are superior to others."

B10

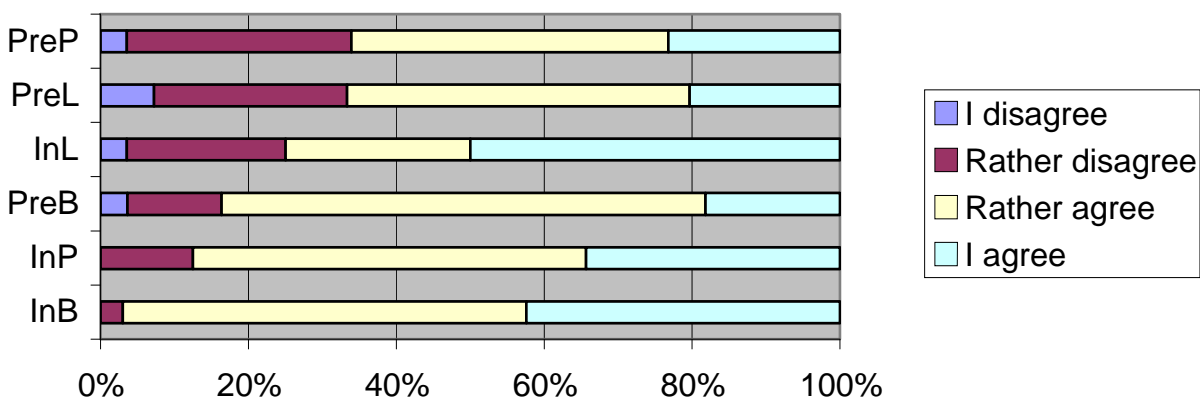


Figure 4. Answers of the six Finnish sub-samples to the question B10 "There are genetic factors in parents that predispose their children to be good in school". InB = in-service Biology teachers (secondary schools) ; InP = in-service Primary schools teachers ; PreB = pre-service biology teachers ; inL = in-service Language (Finnish) teachers (secondary schools) ; PreL = pre-service Language (Finnish) teachers ; PreP = pre-service Primary schools teachers.

Another analysis of our results shows that, in Finland, the biology teachers are more innatist than their non biologist colleagues. The figure 4 is illustrating this point from the answers to the question B10. This figure also shows that the innatism is stronger for in-service teachers than for the pre-service ones: this is a generation effect that we will describe more precisely in an other work. This complementary result suggest two conclusions: (i) the more important level of innatism in Finland could be linked to the way biology was taught and (ii) it could be also linked to the history of the country, more memorised by the oldest teachers.

Conclusions and Implications

In conclusion, the differences pointed by PISA (2006), related to the students' scientific literacy, are not linked, for this precise topic (biological determinism of human features and performances), with differences of teachers' knowledge. There is no significant difference between the Finnish and French answers for almost all the questions dealing with only scientific knowledge (related to human genetic and to cerebral epigenesis).

Nevertheless, there are important differences between Finnish and French answers related to the genetic determinism of human features, behaviour or performances. The convergence of answers from several kinds of questions related to this topic shows a clear innatism in a majority of Finnish teachers answers, and even more when they are biologist and in-service teachers. Moreover, this innatism is partly correlated to some sexist and even racist answers.

This conclusion is illustrating interactions between the taught science (the scientific knowledge K) and implicit values (V). It also shows that the indicators used by international surveys on the scientific literacy (as PISA 2006) are generally ignoring the values that can be linked to some scientific knowledge. Taking more into account these values is an important challenge not only for the international evaluations, but also for the teachers training and the science teaching / learning.

Why these differences between Finland and France? The explanation is not so easy and must be object of more research. We can just propose some very hypothetical suggestions:

The biology syllabuses and textbooks are still teaching an implicit innatism in Finland with a great occurrence of the terms « genetic program » (Castéra *et al.* 2008). The researchers in biology are more and more claiming that the use of these two words is to be avoided, in the research as well as in the biology teaching (Atlan 1999, Jacquard & Kahn 2001). This change is just starting in the French syllabuses and textbooks (Forrissier & Clément 2003). The delay of this change (the DTD = Delay of the Didctic Transposition: Quessada & Clément 2007) is apparently longer in Finland, probably for socio-historical reasons that are still to be analysed.

France is the country of the Revolution, with an early separation between politics and religion (promotion of secular structures: « laïcité »). The history of Finland is very different.

The great debate between innate and/or acquired was very strong in the French media, the most famous French scientists and philosophers being against fatalism from a strong genetic determinism. It was possibly different in Finland?

In our samples, half of French teachers are agnostic or atheist when 2/3 of Finnish teachers are Protestant (Lutherian, when French Protestants are mainly Calvinist): are genes taking the relay of God in the determinism of human behaviour and performances?

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SCIENCE CURRICULUM CHANGE IN ENGLAND: HOW SCIENCE WORKS FOR PRE-SERVICE TEACHERS

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Abstract

This paper reports empirical work conducted by three University teacher education providers into how a major revision of the science curriculum in England, the How Science Works (HSW) strand, has been translated into practice for 14 to 16 year-olds in schools. Data were collected from pre-service teachers about their understanding, experiences, perceived challenges and resourcing of HSW during their final school experience. The results indicate that implementation of HSW in schools lies on a spectrum between two extremes referred to as creative implementation and restricted implementation, a recognition that success with this new approach requires a fuller engagement in higher order thinking skills and the importance of differentiation is paramount if all pupils are to connect with the new curriculum. The paper concludes that support is needed for major transitions in pedagogy with both serving and trainee teachers and that this needs to start with teacher education with greater involvement both in and with University programmes and schools.

Introduction

In a number of European countries such as Germany, Italy and Spain (INCA, 2008), school students follow a statutory national curriculum for science that sets out the requirements for study and assessment. The first National Curriculum was introduced in England in 1989 (DES/WO, 1989) and several revisions between 1989 and 2004 led to four main attainment targets that were essentially scientific enquiry, biological, chemical, and physical processes. One of the most dramatic changes to the National Curriculum for England since its inception, that of How Science Works (HSW), directed teachers to ensure that the knowledge, skills and understanding of HSW are integrated into the teaching of the breadth of study (QCA, 2004). Within the HSW programme of study are four main subsections: data, evidence, theories and explanations; practical and enquiry skills; communication skills; and applications and implications of science. These changes commenced in schools with Key Stage 4 (14-16 years) in September 2006 and with Key Stage 3 (ages 11-14 years) in September 2008.

The purpose of this paper is to examine how changes to a radically altered curriculum – in particular HSW – have been translated into practices in schools as seen through the eyes of pre-service secondary science teachers (trainees).

Rationale

Within the last ten years there have been international concerns about school science education, in particular the uptake of the physical sciences beyond the age of sixteen, gender differences, and students' motivation for studying science (Sjøberg and Schreiner, 2005). The Relevance of Science Education (ROSE) study of students' attitudes to science shows that in over twenty countries students' response to the statement 'I like school science better than other subjects' is increasingly negative the more developed the country (Osborne and Dillon, 2008: 13). Taken with other findings from the ROSE study, this points to students' views that science is 'important but not for me' (Jenkins and Nelson, 2005:41). The international PISA survey (OECD, 2007) note that motivation and attitudes are particularly relevant in science, as it is a subject that does not always appear to be taken up enthusiastically by young people at school.

Alongside concerns about students' views about science education and the uptake of the physical sciences are concerns about what sort of science education needs to be taught in schools. Curriculum change that resulted in the 2004 curriculum originated at the instigation of prominent science educators with a series of open meetings in 1997 and 1998 that culminated in the document *Beyond 2000* (Millar and Osborne, 1998). This seminal document was the product of a desire to provide a vision of science education that addressed the needs and interests of young people as future citizens at the end of the 20th century. One important outcome from *Beyond 2000* was the inception of the Twenty-First Century Science project that was the first attempt to develop and pilot a major curriculum initiative and to use evaluations of the pilot to inform further development (Burden *et al.*, 2007). Further criticisms of the then Key Stage 4 National Curriculum included its prescriptive and assessment driven nature, an overload of factual content, little contemporary science content and coursework that was restricted to a few tried and tested investigations that were divorced from day-to-day science teaching (House of Commons Science and Technology Committee, 2002; Keiler and Woolnough, 2002; Nott and Wellington, 1999; Toplis and Cleaves, 2006).

These developments and criticisms of a curriculum that was content-laden and seen to be lacking relevance to the lives of youngsters resulted in the introduction of a new National Curriculum in 2004 and the adoption by the various examinations boards of new specifications for the examination at the end of Key Stage 4, the General Certificate in Secondary Education (GCSE). Unlike previous centralized curriculum and pedagogical initiatives, no specific in-service training has been available to prepare existing teachers for *HSW*. We were therefore interested to see how these changes to the National Curriculum were translated into practice in schools and to use this information as part of our pre-service teacher training programmes.

In order to find out *HSW* for trainee teachers, we posed two research questions:

1. Is there a paradigm shift in terms of a change in the pattern of science education with a move from teaching facts to understanding concepts? This would represent a change in thinking, or *Mind set*.
2. Is there an associated change in pedagogy in terms of (i) *Mind set* (ii) *Methods* and (iii) *Materials*?

Methods

Three university providers of pre-service teacher education in and around the London area participated in this study with a cohort of 70 trainees during 2008 and 50 in 2009. Trainees study a one year course that includes University taught elements and two blocks of observation and teaching experience in schools.

The study was carried out in two-stages.

Stage 1 involved five questions that were emailed to trainees four weeks before they completed their final period of school experience, to direct their focus on *HSW*. The questions were related to the three aspects of pedagogy in the research questions and provided a stimulus for trainees' thinking about *HSW*.

Question 1: What do you understand by *HSW*? [*Mind Set*]

Question 2: Describe the resources that are being used at Key Stage 4 in your present practice school [*Materials*]

Question 3: What are your experiences of teaching approaches to *HSW* at Key Stage 4? [*Methods*]

Question 4: What challenges have you experienced with teaching *HSW*? [*Methods*]

Question 5: How do you see that pupils receive *HSW*? [*Mind Set*]

Stage 2 involved small discussion groups (3-4 trainees) in the final weeks of the University course. The discussion started with one of five questions. The trainees were then asked to summarise their discussions on a poster. They then went to the next questions and repeated the process adding to the responses recorded by the previous group. The data collected from the email responses and from the posters from the discussion groups of the three University providers were analysed collaboratively to discuss, code and categorise emergent themes.

Pre-service teachers are in a unique position to collect data during their school block experience as they have become participants in their communities of practice in schools. As participants they have access to the schools', the pupils they teach and the work of teachers.

They can also benefit from the thoughts and practices of established teachers through observing lessons, meetings and feedback on their own supervised teaching in science classrooms. As the trainees come with a limited experience of the recent history of school science under the National Curriculum, they are in a position to view science education in schools with an uncluttered perspective.

This is a longitudinal study, gathering data over a period of three years. The project is now in its second year. The approach to obtaining data continues to be the same in all cases.

Detailed analysis will be available in a full report, but for the purposes of this paper, only the key indications will be highlighted.

Results

Overall trends

What do you understand by HSW?

Between 2008/2009 there was a noticeable trend towards:

- More mention of historical aspects of *HSW*, including famous scientists, discoveries and development of theories.
- A growing understanding of the importance of communication, that ranges from the use of scientific vocabulary and presentation skills by pupils, to putting everyday concepts into perspective and debates about how science affects society.
- An emerging recognition of the need for higher order thinking skills that relate to understanding science concepts rather than a recall of scientific knowledge.

This last point is a noticeable change in the discourse of trainee science teachers over the period.

There was no change in students' views about scientific investigation (data, samples, reliability and validity) or the application of science to everyday life.

Describe the resources that are being used at KS4 in your present practice school

In both 2008 and 2009, data showed that schools place a heavy reliance on published schemes including textbooks, specifically linked to examination board specifications; published worksheets and questions, and ICT materials that included multi-media CD packages such as simulations, web-based resources included video clips and materials and presentation based on PowerPoint.

There was very little evidence of teachers and science departments developing their own 'bespoke' materials.

What are your experiences of teaching approaches to HSW at KS4?

Data indicated a strong dichotomy in response. In the few schools who had taken a determined approach, the changes had been positive.

- Improvement in the way practical investigations were being presented and managed by teachers, with pupils being more involved and learning more effectively.
- There was an increase in the use of role-play, the development of anecdotes, the use of animations and topic research to support conceptual understanding.
- The new approach develops imagination, encourages participation and provides more opportunity to be creative.
- Students take more responsibility for their own learning.

With many schools, however, there were still areas where there was little evidence of progress.

- There is a continuing lack of help and support to teachers who remain not well informed and still unsure of what is required.
- Lack of resources makes it difficult and time consuming.
- This approach continues to challenge lower ability pupils, whose understanding of vocabulary, lack of prior knowledge and the need for higher order thinking skills results in diminished interest and motivation.
- Many teachers are still teaching pupils to pass examinations.

What challenges have you experienced with teaching HSW?

Between 2008 and 2009 challenges involving the practicalities of teaching *HSW* reduced noticeably. These included the need to convince pupils that *HSW* was still science and making them aware of the aims and the links to science, for example, "*students used to being fed facts, many just want to sit and answer questions out of a textbook*". There were further problems with providing the right level of guidance for practicals and making sure all pupils were involved in discussions.

This is seen as an inevitable consequence of the process of embedding curriculum change. However, there was a re-emergence of scientific content and the need for content to be discussed; the proportion of this category increased from 2008 to 2009.

There was no change in the assessment-driven nature of the curriculum over the two cohorts. Pupil ability still remains a key factor and an ongoing challenge.

How do you see that pupils receive HSW?

There appears to be an increase in reports of the engagement and enjoyment of pupils in science from 2008 to 2009, especially so for the more able.

Problems still remain in terms of differentiation. Evidence indicates that where higher ability pupils are challenged, they enjoy science and respond well, particularly where higher order thinking skills are involved. However, where science is insufficiently challenging, their response is negative. Lower ability pupils find some of the work too challenging but respond well when it is tailored to their needs. By higher order thinking skills we mean those skills such as analysis, synthesis, evaluation and creativity that appear higher in the revised Blooms Taxonomy (Anderson and Krathwohl, 2001).

Conclusions and Implications

There is every indication that this new approach to teaching science, *HSW*, is a positive step that engages, enthuses and challenges pupils giving them a deeper understanding, interest and insight into the concepts and nature of science. *HSW* is definitely well received by pupils.

Our data indicates that how *HSW* is adopted in schools lies on a spectrum between what we refer to as creative and restricted implementation.

Schools that have engaged creatively in this process of transition are recognising the importance of developing historical context, communication and research skills; as well as the basic practical skills of experimental work.

Many schools have not, and continue to be hampered by restricted view towards curriculum change characterised by a lack of motivation, formal support and resources.

Restricted implementation is understandable, given the pressures on the teaching profession that include financial, assessment linked to success in national league tables, reduced in-service training, innovation overload and inertia.

There is recognition that in order to benefit fully in this process, students need to be challenged into developing higher order thinking skills. Low ability pupils can be left demotivated, with difficulty in developing vocabulary, debating skills, conceptual understanding and the ability to work independently. The underlying issue throughout is differentiation.

Implications to Teacher Training

Trainee teachers cannot be guaranteed a full and engaging introduction to *HSW* in their practice schools.

Some form of intervention for *HSW* needs to be introduced into Initial Teaching Training Programmes.

In this way, trainee teachers will not find themselves at a disadvantage when required to bring this new approach to their pupils.

Giving our trainees this additional input may also help the process of transition as they go out into schools and are able to spread the word.

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THE EFFECT OF DESIGN OF REPRODUCTION AND GROWTH OF LIVING SPECIES UNIT IN PRIMARY SCHOOL EIGHTH GRADE SCIENCE COURSE CURRICULUM ON THE ACQUISITION OF BEHAVIORS AIMED

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Abstract

The purpose of this study was to create a laboratory environment in which students could behave like scientists. In this study it is aimed to increase the success of "Reproduction and Growth of Living Species" unit which is in the eighth grade Science course curriculum that is to reach the targets anticipated by Ministry of National Education's primary education curriculum of 2000. All processes of this unit, which is in the curriculum of Science course, have been rearranged according to the 5E method regarding constructivist training approach. In the present study experimental model (pre-test and post-test with control group) has been used. The study included 70 students from two separate 8th grades at Zekai Gümüşdiş Elementary School located in an urban area in Bursa in Turkey. The applications, which were planned as three hours per week, lasted 9 weeks in 2004-2005 academic year spring term. Unit acquisition tests developed by the researcher were used as data collection instruments in the present study. In the data analysis, the SPSS 11.0 was used for t-test calculations. Consequently, the training program which was design by the help of constructive approach has helped students acquire eight target behaviors.

Introduction

Instructional programs, within curriculums, are guides which show what will be taught to students, the targets to be reached, how the behaviors that are appropriate to the targets will be acquired, and which training techniques, in what sequence, and how much will be used in this process (Varış, 1996; Erden, 1998; Özçelik 1998; Demirel 2003, Küçükahmet, 2004; Senemoğlu, 2004). In science and technology fields, teaching methods and tools need to be reevaluated appropriate to improvements and changes. It would be beneficial to add different approaches to topics as well. Among the topics of science the unit that is most difficult to teach is "Reproduction and Growth of Living Species" unit. There is need for special care in reconstruction of wrong and incomplete information acquired about biological matters.

All processes of this unit, which is in the curriculum of Science course, have been rearranged according to the 5E method regarding constructivist training approach. The curriculum that has been designed is formed of five phases that are engaging, exploring, explaining, elaborating, and evaluating. Additionally, integration of students' previously acquired information with the new information that was brought by the design has been considered so that they would be internalized during application which is very important.

¹ This paper is adapted from the first author's master thesis "A Study On The Curriculum Design For The Organization And The Teaching Of The Subject "Reproduction And Growth" in Primary Education Science Courses" submitted to Uludağ University under the supervision of Prof. Dr. Muhlis Özkan.

In this study it is aimed to increase the success of “Reproduction and Growth of Living Species” unit which is in the eighth grade Science course curriculum that is to reach the targets anticipated by Ministry of National Education’s primary education curriculum of 2000.

Methods

2.1) Research Design

The experimental method was used in this study. The pre-test post-test design with control group method was employed. The study included 70 students from two separate 8th grades instructed by the researcher at Zekai Gümüşdiş Elementary School located in an urban area in Bursa in Turkey. This study was carried out with two classes selected randomly. One class was randomly assigned to the experimental group (n=35; 22 girls and 13 boys) while the other group formed the control group (n=35; 19 girls and 16 boys). The average age of the participants was 13-14 years. The study was conducted over a 9-week period in the spring term of 2004-2005 academic years. All participants attended three hours lecture per-week in a science course. In this study, according to the 5E learning cycle according to which the program was developed was applied to the experimental group and traditional program was used in control group.

2.2) Data Collection

In this study, unit acquisition test was used as data collection tool, in order to determine the attainability of the anticipated targets of the unit to be acquired by the students. A specialist university lecturer and experienced Science course teachers were applied for the appropriateness of the questions to the unit and their measurement value. The test contains totally 32 multiple choice questions, each having four options, which examine 28 gains. For the internal validity of the test, Cronbach’s alpha reliability value was determined as 0,76. The unit acquisition test was applied to all students in the experimental and control groups as pre-test and post-test. The data conducted in the study were analyzed with the help of SPSS 11.0 package program.

The scores that students in the experimental and control groups acquired from pre and post tests were analyzed in the SPSS 11 program within 95% reliability interval where t-tests were done for dependent and independent groups, and comparison was done within the groups and among groups. Additionally, item difficulties were calculated.

Results

The data collected were analyzed using appropriate techniques and were converted into tables and interpreted. Conducted results were as in the following:

The scores that experimental and control groups acquired from the pre-test and post-test were compared with t-test in independent groups, and no significant difference was found between the two groups ($t_{\text{pre-test}}=0,61$; $p > 0,05$; $t_{\text{post-test}}=0,49$; $p > 0,05$).

In order to determine whether there was a significant difference between the scores of experimental and control groups in the pre-test and post-test, t-test was conducted within those groups separately in dependent groups and the obtained results were shown in the table. According to these results, there was a significant difference in both experimental and control groups pre-test and post-test scores.

Table 1. The t-test comparison of experimental and control groups' pre-test and post-test scores in dependent groups.

Groups		n	X	S	sd	t	p
Control Group	Post-Test	35	18,11	4,68	34	6,54	0,00*
	Pre-Test	35	13,51	3,49			
Experimental Group	Post-Test	35	17,54	5,06	34	7,40	0,00*
	Pre-Test	35	12,94	4,30			

*p<0.05

Table 2. The behaviors that experimental and control groups acquired after application.

GROUP	Acquisition	Acquired Behaviors
	Number	
EXPERIMENTAL AND CONTROL (EC)	1	Explains that Reproduction, which is the common speciality of living species, is the ability to generate living species similar to them.
EC	18	Explains the fertilization of sexual cells of human beings.
EC	22	Sequences the positive factors that contribute to growth and development of human being, and specifies examples.
EC	24	Sequences the phases of growth and development process of human beings.
EC	27	Specifies the sexual diseases and ways of protection.
C	7	Explains that chromosome numbers and contents (the genes comprised) can be different in different living species, and proposes reasons for that.
C	19	Demonstrates with schemas the development phases from fertilized egg until becoming a baby.
C	23	Sequences the negative factors that contribute to growth and development of human being, and specifies examples.
C	26	States the problems faced in transition from infancy to puberty, and discusses the examples proposed for ways of solution.
E	4	Indicates that DNA, which is the genetic structure in the cell, both manages the cell life and pairs itself so that enables same specialities to be passed to the new cells.
E	16	Explains sexual reproduction and gives examples for species that generate through sexual reproduction.
E	25	Gives examples for physical and spiritual changes in female and male children during puberty.

Additionally, in the study, in order to see in which behaviors difference occurred between the curriculum that was designed with the help of constructivist approach, and the traditional curriculum, item difficulties were examined. Estimated item difficulty values were taken as measure for accessibility to acquisitions. In the last test each acquisition that met $P_i \geq 0,7$ condition was acquired by the students. According to this, students at the experimental group have acquired 8 of the total 28 behaviors, and the control group students have acquired 9 of the behaviors. As seen in Table 2, control group has acquired 1, 7, 18, 19, 22, 23, 24, 26, 27 numbered behaviors, and the experimental group has acquired, 4, 16, 18, 22, 24, 25, 27 numbered behaviors.

Conclusions

The scores of experimental and control groups attained from the pre and post tests have been compared with t-test in independent groups, and no significant difference has been found for both tests between the two groups. Moreover, in independent groups it was checked with t-test whether there was a significant difference between the scores of the experimental and control groups attained from the pre-test and post-test, and ultimately it was determined that there was a significant difference both in experimental and control groups. In order to find out in which behaviors a significant difference existed between the curriculum designed according to 5E method, and the traditional curriculum, item difficulty values were analyzed. The designed program has helped students acquire totally 8 target behaviors. Three of these eight behaviors were realized as a result of accessibility success of the anticipated targets designed with the constructivist approach.

Implications

- 1) It is necessary to place more activities, visual aids and aids in the training program of Reproduction and Growth of Living Species unit.
- 2) Preparation questions should be of that quality to assess MNE's (Ministry of National Education) acquisitions which take place after topic explanation. Additionally, the unit should be supported by study papers and demonstrations on computer environment.
- 3) To teach the Reproduction and Growth of Living Species topics in a more permanent way, it is certainly necessary that teacher determines and evaluates the prejudices and previously acquired knowledge. The help of school management and families is needed during the teaching of the unit. It is necessary that this matter be taken into consideration in the design of the curriculum.
- 4) During the practice of unit should be benefited from models, tables, signboards, acetates, etc. accelerates learning since experiments are limited and observations related to especially development take long time.
- 5) During the teaching of unit, it was determined that benefiting from flowcharts, concept maps, games, and tables that summarize the topic positively affect students' acquisition of some terms.

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THE COMPARISON OF THE REPRESENTATION OF SCIENCE PROCESS SKILLS IN 9TH GRADE CHEMISTRY CURRICULA: GERMANY, FRANCE, CANADA AND TURKEY

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Abstract

This study aims to compare 9th class chemistry curriculums in terms of scientific process skills included in Germany, France, Canada and Turkey. The attainment targets and the activities included in the curriculums, and the relationship between the types of the questions and the processes, were analysed in terms of scientific process skills included by using document analysis. The findings show that; in these countries, basic scientific process skills are represented in 9th Class Chemistry Curriculums from maximum to minimum qualitative in this order Turkey, France, Canada (Manitoba) and Germany (Stuttgart). Higher level scientific process skills are represented from maximum to minimum qualitative in this order Germany (Stuttgart) and Canada (Manitoba). As a result, in these countries, the scientific process skills in 9th Class Chemistry Curriculums included from maximum to minimum quantitatively in this order Germany (Stuttgart), Turkey, France and Canada (Manitoba).

Introduction

Student-teacher and curriculum triangle is crucial in order to reach the aims of science education which is defined as thinking of the nature of knowledge, understanding of the existing knowledge and the process of knowledge production (McMinn et al., 1994: 755-758). In this triangle, the role of curriculum has major importance. It cannot be denied that a well designed curriculum increases the performance of teaching and learning (Ayas et al., 1994, 30). The efficiency of education could be increased through getting learners adopt a habit of scientific process skills. Scientific process skills are thinking skills which are used in constructing knowledge, thinking on the problems and formulating of the results. The skills are the skills used by scientists in scientific studies (Lind, 1998). Gagne (1965) suggests that what should be taught to the children should be similar to what scientists do. Scientific process skills are the methods by which scientists use them to reach the knowledge and process the data. Scientists observe, classify, measure, draw conclusions, construct the hypotheses and do experiments. The Association of American Science Progress (A.A.A.S.), classifies scientific process skills into two groups; Basic and Integrated Scientific Process Skills. Basic scientific process skills are observation, classification, recording of the data, measurement, use of the space and time relationships, use of the numbers, inference, and prediction. These skills help to learn Integrated Science Process Skills (changing and controlling the variables, interpretation, construction of hypotheses, operational definition, using the data and formulation of models and experimentation) which are more complex skills compared to the basic process skills (Padilla & Okey, 1984).

In this study, the aforementioned curriculums were analysed in terms of total fourteen scientific process skills (Basic Process Skills including observation, classification, communication, measurement, prediction and inference, and Higher Level Process Skills including identification, manipulation, interpretation, operational definition, formulation of models, experimentation, construction of hypotheses, drawing conclusions) (G.D.E., 2004). This

study specifically aims to answer these following questions: How scientific process skills are represented in 9th class chemistry curriculums in Germany (Stuttgart), France, Canada (Manitoba) and Turkey?

The scope of this study is limited with 9th class chemistry curriculums in Germany (Stuttgart), France, Canada (Manitoba) and Turkey. The reason of this is; In Turkey, contemporary chemistry curriculum framework is suggested by Aydın in 2004 (Aydın, 2004). 9th class chemistry curriculum was prepared by the Ministry of National Education and started to be implemented in 2007 (M.E.B., 2007). Then, 10th class chemistry curriculum was prepared in 16.06.2008 and will be firstly implemented in 2009-2010 academic year (M.E.B., 2008). 11th and 12th years chemistry curriculums have not prepared yet. Therefore, in this study, only 9th class chemistry curriculum was analysed.

Why only German (Stuttgart), French, Canadian (Manitoba) and Turkish curriculums were analysed?

These countries were selected according to their success in the PISA 2006 report (PISA 2006, p.31). According to this report, Canadian students are in the fourth competency level, German and French students are in the third level, and Turkish students are in the second competency level. The difference between the performances of the students is based on different factors; such as; i) the relationship between the science performance of students and their socio-economical backgrounds, ii) the relationship between the science performance of students and the national income, and iii) the differences between within schools and interscholastic (PISA 2006, p.77). In this study, as an another variable, the representation of the scientific process skills included in the curriculums were analysed.

Methods

In this study, document analysis method was used. In this analysis, the relationship between the processes, questions and the types of questions were examined. In this analysis, the questions and the types of questions whose reliability and validity were tested, were used. In these questions, it was determined that which processes are related with joined questions and which questions are related with departing questions (Turgut et al., 1997: 5.4).

After that, a question list was used as a measurement tool. The attainment targets and the activities included in the curriculums, and the relationship between the types of the questions and the processes, were analysed in terms of scientific process skills included by using document analysis. It was found that which scientific process skills are mostly represented in the topics and in the questions related to the topics.

Results

The results of this study were summarised in Table I. According to this table, when the percentages of the topics analysed; “prediction”, “identification” and “interpretation” skills were mostly included skills in Canadian (Manitoba) curriculum; “formulation of models” , “manipulation” and “experimentation” skills were mostly included skills in German (Stuttgart) curriculum. In French curriculum, “observation” and “communication” skills; in Turkish curriculum, “classification” and “measurement” skills were the mostly included skills.

Conclusions and implications

The aim of chemistry education should be preparing individuals to have knowledge, skills and attitudes. This could be provided by teaching of science process skills. In this study, 9th class chemistry curriculums were analysed in terms of science process skills included. From the curriculums analysed, it is apparent there are differences between the importance given to science process skills in these four countries.

In Canadian (Manitoba) curriculum, from the basic process skills; “classification” and “prediction” skills, and from the higher level process skills; “identification”, “interpretation” and “formulation of models” skills were sufficiently included.

In German curriculum, from the basic process skills; “Observation” skill, and from the higher level process skills; “Identification”, “Manipulation”, “Formulation of Models” and “Experimentation” skills were sufficiently included.

In French curriculum, from basic process skills; “Observation”, “communication”, and “Measurement” skills were sufficiently included however, higher level process skills were not sufficiently included.

In Turkish curriculum, from basic process skills; “Observation”, “Classification”, “Measurement”, and “Prediction” skills were sufficiently included however, similar to French Curriculum, higher level process skills were not sufficiently included.

As a result, in these countries, the scientific process skills in 9th Class Chemistry Curriculums included from maximum to minimum quantitatively in this order Germany (Stuttgard), Turkey, France and Canada (Manitoba).

From this, it should be suggested that in order to prepare students to have more knowledge, skills and positive attitudes, chemistry curriculums should include more scientific process skills.

Table 1: The science process skills included in 9th class chemistry curriculums (G.D.E., 2004)

Country	Name of the unit	Basic Process Skills						Higher Level Process Skills							TOTAL	
		1- Observation	2- Classification	3-Communication	4- Measurement	5- Prediction	6- Inference	7- Identification	8- Manipulation	9- Interpretation	10- Operational definition models	11- Evaluation of models	12-Experimentation	13- Communication of hypotheses		14- Drawing Conclusions
Germany (Stuttgart) (Hector,1994,p.385-387)	Matter and Reaction	5	-	-	-	-	-	10	-	-	-	-	-	-	-	15
	Air, Oxigen,Oxidation	-	-	-	-	-	-	-	5	-	-	-	-	-	-	5
	Water,Hydrogen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Quantitative equations	-	-	-	-	-	-	-	-	-	5	5	-	-	-	10
	Alcaly Metals and calciyum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Halogens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	TOTAL	5	-	-	-	-	-	10	5	-	-	5	5	-	-	30
%	16.6						33.2	16.6			16.6	16.6			100	
France(CNDP, 2001, 9-55)	Measuring in chemistry	7	-	-	15	-	-	-	-	-	-	-	-	-	-	22
	Creative chemistry	4	-	2	-	-	-	-	-	-	-	-	-	-	-	6
	Daily energy-molecular bonds of the matter and its energy changes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	TOTAL	11	-	2	15	-	-	-	-	-	-	-	-	-	-	28
	%	57,1		7,1	35,71											100
Canada (Manitoba) (Senior 2, 2009, pp.2-2-2.39)	Elements and Periodical Table	-	-	-	-	2	-	1	-	-	-	1	-	-	-	4
	How elements form compounds	-	-	-	-	1	-	-	-	-	-	2	-	-	-	3
	Activity: Ionic changes and chemical families	-	-	-	-	1	-	-	-	-	-	2	-	-	-	3
	Ionic compounds	-	-	-	-	-	-	1	-	1	-	-	-	-	-	2
	Molecular compounds	-	-	-	-	1	-	-	-	1	-	-	-	-	-	2
	Chemicals and chemical change	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Case study: Hazardous household chemicals	-	-	-	-	-	-	2	-	1	-	-	-	-	-	3
	Investigation: measuring masses in chemical changes	-	-	-	-	-	-	2	-	1	-	-	-	-	-	3
	Conserving mass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Finding the missing mass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Word equations	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
	Balancing chemical equations	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Combustion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Types of chemicals reactions: Synthesis and decomposition	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Investigation: Putting things together	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Investigation: Taking things apart	-	1	-	-	-	-	2	-	1	-	-	-	-	-	4	
Types of chemicals reactions: Single and double displacement	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Investigation: Single displacement reactions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Investigation: double displacement reactions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Activity: Putting It all together	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Investigation: Recognizing acids and bases	-	-	-	-	1	-	2	-	-	-	-	-	-	-	3	
Properties of acids and bases	-	-	-	-	1	-	2	-	-	-	-	-	-	-	3	
The pH scale	-	-	-	-	1	-	2	-	-	-	-	-	-	-	3	

	Investigation: Household products and pH	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2
	Investigation: Testing antacids	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Case study: Putting It all together : acids and bases in Industry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Investigation: Reacting acids and bases	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Neutralization reactions	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Acids Deposition and Forest Ecosystems	-	-	-	-	1	-	2	-	-	-	-	-	-	-	3
	Investigation: Assessing the effects of acid rain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Explore an Issue : Is pollution necessary?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Debate: The sale and use of cars should be restricted	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Case Study: Air pollution and acid precipitation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Investigation: Acid precipitation and buildings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Explore an Issue : Is pollution necessary?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Rates and Automobiles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Case Study: Air pollution and precipitation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
TOTAL	-	1	-	-	6	-	13	-	4	-	3	-	-	-	27	
%		3.7			22.2		48.1		14.8		11.1				100	
<i>Turkey</i> (M.E.B., 2007, pp. 22-59)	Development of chemistry	-	-	-	4	2	-	-	-	-	-	-	-	-	6	
	Compounds	-	-	-	7	1	-	-	-	-	-	-	-	-	8	
	Chemical changes	1	-	-	4	-	-	-	-	-	-	-	-	-	5	
	Mixtures	-	-	-	3	-	-	-	-	-	-	-	-	-	3	
	Chemistry in our life	-	2	-	5	-	-	-	-	-	-	-	-	-	7	
	TOTAL	1	2	-	23	3	-	-	-	-	-	-	-	-	29	
	%	3.44	6.89		79.31	10.34									100	

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ANALYSING THE SUPPORT FOR AND OBSTACLES TO INTEGRATING EDUCATION FOR SUSTAINABLE DEVELOPMENT IN FRANCE

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Abstract

Education for Sustainable Development (ESD) in France has been in its second phase of integration since 2007. The research programme that is the focus of this presentation looks to analyse the purpose and the values associated with this educational approach on the one hand, and to identify the support and obstacles linked to its integration on the other. Therefore it concerns directed research whose results will be diffused mainly to executives and practitioners, be they educators and coordinators at museums, or heads of environmental education planning. This approach behooves us to diagnose and to conceptualise the basic question of feasibility. Our research project therefore consists in identifying and conceptualising the elements of our interpretation not only of the gap between prescribed and actual curriculum, but also of that between the possibilities proposed by researchers and those that can actually be carried out. These elements will form the core of the contribution to the research to be undertaken. At this stage, they are expressed in terms of hypotheses subject to corroboration according to support and obstacles, difficulties and academic conservatism, concerning as much axiological, didactic, epistemological, and ontological aspects as pedagogical ones.

Introduction

The research programme “Education for Sustainable Development: Support and Obstacles” lasts for a duration of four years and receives financial support from the French National Research Agency (ANR)¹. It is a consortium of four main laboratories:

- UMR STEF (Sciences, Techniques, Education, Training) Ecole Normale Supérieure (ENS) de Cachan /INRP, Cachan

¹ (ANR-08-BLAN-0135-01).

- Research Unit in Didactics of vocational, scientific, social and emerging knowledge (overseen by L. Simonneaux), Ecole Nationale de Formation Agricole (ENFA), Toulouse
- UMR ADEF (Learning, Didactics, Assessment, Training) (overseen by A. Legardez), University of Provence/INRP, Marseilles
- Museology and Mediation of Science Unit (overseen by Y. Girault), Museum National d'Histoire Naturelle (MNHN), Paris

In France, according to the *national sustainable development strategy*, Education for Sustainable Development (ESD) entered its second stage of generalization in 2007. French guidelines require enrichment on all academic levels, disciplines, and curricula and at the same time require a non-discipline specific approach and implementation on an establishment-wide scale.

Our project aims to investigate the support, difficulties and obstacles which are at work in the process of general application: in short, to make intelligible the **feasibility** and outcome of this top-down process in a formal and non-formal context.

This programme is, in accordance with P. Hart's (2007) analysis, in line with international research aimed at understanding the decision-making processes with the protagonists in the context of incomplete data, insecurity, contradictory demands and plurality of values. We try to understand how structures and teachers incorporate this political directive: their willingness to accept it, creativity, and difficulties in meeting with protagonists.

Context of the Research

In reference to institutional texts encompassing the two phases of the integration (BO, 2004, 2007), the "Intergovernmental Panel on Education for Sustainable Development" (Brégeon, Faucheux, Rochet, 2008) stresses that to move from a phase of experimentation to one of integration requires a considerable research effort. The objective of our project is to assist in clarifying the stakes and the terms of this undertaking. In the French education system, the guidelines concerning ESD require the enrichment of all academic levels, disciplines, and programmes. Accordingly, the coherent education strategy of our mission depends on the advantage of being non-discipline specificity, if only because of the political and social nature of what is at stake.

The curriculum could be determined (and driven) in three ways (Ross, 2000):

- according to contents (content driven)--organised by discipline or subject, for example;
- according to stated aims (objective driven)-- ones concerning skills, for example;
- by procedure (process driven)--educational initiatives, for example.

This last method offers the advantage of being compatible with a non-normative and non-utilitarian educational objective. It also provides the conditions necessary for the fostering of abilities (Bourdieu, 1998), that is to say, attitudes and habits of choosing, deciding, and acting in accordance with a well-considered development that distinguishes itself from the one in place, without prejudging or imposing non-collective or non-negotiable solutions; yet the designing of a curriculum centred on educational initiatives in the form of collaborative teaching experiences is at odds with traditional education centred on knowledge. Its relationship to skills, which has recently been made obligatory in French education, also demands clarification: if the experience contributes to the fostering of abilities whose employment is indeed made possible by the resource of knowledge, the particular types of abilities relative to ESD are far from attaining an accepted and stable definition. The common ground between the aims of this educational approach on the one hand, and its underlying values, its aptitude goals, and the knowledge employed in retained classroom activities, on the other, remain to be clarified.

Moreover, in the context of strictly discipline-oriented education (particularly in secondary schools), the question arises of the contributions made by disciplines, and one must wonder to what extent this evolution of the disciplines taught can (and should?) be stimulated by the expansion of ESD, as much regarding concepts of referential methods as those of effective practices. Thus, various researchers are working today on the trend of controversies in the teaching of the sciences, be they "hard" or social sciences, in a framework of "critical" citizen education (Fortin Debart and Girault 2009; Girault, Auzou, and Fortin Debart 2008, Legardez and Alpe 2001; Simonneaux, 2001; Kolstoe, 2001; Albe and Simonneaux, 2002; Sadler, Chambers and Zeidler, 2004; Simonneaux and Simonneaux, 2005...), considering that one of the goals of science teaching is the development of an understanding in students of the interdependence of science and society. Today, following the Science-Technology-Society (STS) educational movement, the Science-Technology-Society-Environment (STSE) movement has developed. This field involves the study of controversial scientific issues. Legardez and Simonneaux (2006) speak of "Socially Acute Questions" in science, social services, and in society as a whole, and therefore in education with regard to a variety of scholarly instruction, such as that of human-environment linkages. The notion of "socio-scientific issues" (SSI) has been introduced as well by educators to describe the social dilemmas associated with scientific fields (Gayford, 2002; Kolstoe, 2001; Sadler *et al.*, 2004 a et b; Zeidler *et al.* 2002). It concerns contentious issues which bear on one or more of the following interests: biological, social, ethical, political, economic, and environmental (Girault Y., Quertier E., Fortin Debart C., Maris V. 2008).

The research in both formal and non-formal education, relying on the contributions of the STS, STSE, SSI, and Science Studies movements, as well as on work concerning SAQs and curricular approaches, must facilitate the characterisation of the conditions of the integration of scholarly disciplines in the ESD project, their connexions, their respective contributions, and their limits. It will have to examine the essential concept of sustainable development within the dual framework of epistemological and critical-ontological perspectives.

Rationale

The aim of this programme is to define and to analyse the main support and obstacles that demonstrate the feasibility, and the potential inconsistencies, of integrating the ESD. Which teaching models could be applied to trans- or non-discipline specific cases, that is, to those that do not depend on a disciplinary approach? How can we see that the implemented educational initiative confronts actual social problems and actions, with an eye to making a contribution to a critical eco-citizenship? What types of teachers' engagement will it require? Which progressive principles should be taken into account? Upon what support can this new model be founded? What kinds of obstacles, such as lack of interest, academic conservatism, and misuse, will these initiatives come up against? How should one train teachers and coordinators in these new approaches, in these news modes of implementation, without compromising their critical perception? What suggestions could help to modify these approaches?

In the educational context, and without denying the role of all actors (administrators, community leaders; parents and their organizations; ESD spokesmen and associations; students; families and peers) play in the ESD, it would indeed seem that teachers hold a primary position in this system and that their abilities, their values, and the nature of their commitment remain critical, all things considered. It is the combination of these parameters that constitutes the focus of the current research project. Therefore the first aim of this project is to formulate a typology of the modalities of educational initiatives suggested in available publications, and to evaluate as much the requirements of their implementation as their consequences and implications. Taking into account this report, we hope, secondly, to enter into a cooperative approach with teachers to building new educational models. This ambition raises several issues of pertinence and consistency in the academic undertaking of the challenges of sustainable development: standards of acceptability for the various actors according to their values and their performance of teaching guidelines; the integration of disciplines; and the progress of the development of form and content throughout the studies.

If the ESD can be designed according to the three modes defined above (Ross, 2000), it is nonetheless evident that the third item (process driven) appears more consistent with the specific mission. To formulate in this way the crux of the ESD spares us from reducing everything to disciplinary structures (for lack of an ability to imagine otherwise); from 'new' plans of action restricted to the acquisition of skills, without the cultivation of *abilities*--that is to say, in this case, attitudes and habits (Bourdieu, 1998). This enables one to choose and determine initiatives, such as the subjecting of territorial development to standards of sustainability. This curricular approach, however, permits the evaluation and diagnosis of gaps between the *prescribed* and *current* curriculum in a less naive manner, in particular the curriculum 'experienced' by students. It allows a much freer reflection on what is possible. It furthers the study and understanding of the disparity between current and prescribed, the range of teachers' possibilities, of *feasibility*, namely the support and the obstacles--on the institutional, professional, or didactic levels (indeed in terms of values and purpose)--pertaining to the widespread establishment of all aspects of the ESD. The aim of the programme, therefore, is to diagnose the conditions for the ESD's feasibility in the context of its integration, and to evaluate its relevance, effectiveness, and its efficiency.

This programme would contribute in this way to building a reference tool to be utilized by executives and teachers to analyse the generally desirable relevance and conditions of the integration of the ESD.

Methods

The programme involves a team of thirty researchers in the didactics of experimental science, techniques, history and geography, human and social sciences, and citizenship education, specialists in museology and environmental education.

We work together in accordance with a "*multireferentiality*" method: Each researcher works in accordance with his own framework and together we build an "*island of intelligibility*" (Simonneaux, J. *et al.*, 2006).

We address:

- Curricular points of view (J.-M. Lange)
- Socio-scientific-issues (L. Simonneaux and A. Legardez)
- Territorial Intelligence (A. Legardez)
- ERE and non-formal education (Y. Girault)

If we have different frameworks, we share some ideas about the relationship between: Sciences-Technique-Society and Sciences-Technique-Society-Environment, Sciences Studies and Science Literacy, a critical and non-normative approach of ESD, importance of debates, and the necessary and currently, deficient, role of sciences and technique in ESD.

The research group functions then according to the principle of the *learner-community* (Argyris et Schön, 1978; Guiterrez et Stones, 1997). The employed methodology is with a non-normative and non-prescriptive intent, which implies the consideration of a wide variety of situations which make possible the identification and analysis of the plurality of possibilities.

Main inquiries

Our main inquiries are as follows:

To reveal and characterize political and epistemological presupposition and contradiction within international and national prescriptives

To characterize the institutional response (changes, inputs, renunciations, resistance, compromise made by the various level of the hierarchy of policy-makers)

To identify and classify innovations and identify the personal motivation of the project leaders in school

To ascertain the role of local institutions and organizations

- To identify the impact of ESD on the reconstruction of disciplines
- To identify the impact of ESD within the diversity of territories
- To identify interactions between formal and non-formal settings
- To identify pupils' conceptions and the degree of engagement of pupils and students, especially pupils with social or learning difficulties
- To identify Supports and Obstacles through ESD experimentations.

Results

The programme began in January 2009, but we can present some trends concerning formal curricula, practices of teachers, pupils and students, and about informal education.

Formal curriculum

- In according with an epistemological analysis of SD, there is a major risk of biased drift according with a purely economic conception of environment and considering only Science and Technique as a solution
- Concerning the top-down approach, there is a real involvement of educational institutions but also a major risk of narrowing the school's remit to merely utilitarian ends, and a risk of normativeness according with an ideology of Good Practice which brings ESD to a simple juxtaposition of promoting events but not building a coherent curriculum
- From the point of view of the disciplines, the risk is of observing a reinterpreting of pre-existent curriculum but not a deep reconfiguration of contents. Disciplines should not be considered in isolation but interdependently
- From the point of view of epistemology, there is a break with usual practices: the contract is to discover valid answers. In ESD, students have to deal with doubtful problems and unvalued resolutions.

The practices of teachers

- There is a tendency to undertake a simple covering of usual practices
- There is also a difficulty in establishing a dialogue with partners and local decision-makers
- The usual organization in class and within the disciplines prevents actions on the scale of the larger establishment: it raises the question of organization and governance within schools
- There is also a difficulty in taking part in collaborative jobs and a profound opposition between the proponents of a school dispenser of knowledge anchored in each discipline and the supporters (including by relatives and within the associations) of a school more pragmatic, which emphasizes, in the framework of a society in crisis, the know-how, the acquisition of "good gestures" like citizens.

Pupils and students

- From the point of view of the pupils, there is difficulty in responding to an "invisible teaching" (versus a model of "visible teaching" of students, consisting of moments of class discipline, textbooks, summative evaluation, course notes to learn... (Lebeaume, 2008; Bernstein, 1997)) and some teenagers have difficulty in seriously putting their minds to questions of the future
- Difficulty in overcoming the emotional position engendered by local questions

Informal education:

- There is most often a simple superficial changing of usual practices in EE and difficulty in finding characteristic features of ESD in comparison with environmental education.

Conclusions and Implications

The programme has begun, and we have only some temporary results (cf in this conference communication and poster: L.Simonneaux & J. Simonneaux; Saji & Lange). But it seems important to say that the diversity of approaches is a necessary condition for the understanding of the complex problem of ESD feasibility. To avoid a simple juxtaposition of pieces of research and favour real interactivity, several cross-disciplinary workshops and a theoretical database were set up. They are the object of exchanges on an online workgroup and a biannual seminar.

One conclusion follows: there is not help or obstacles by themselves, but both at the same time.

Therefore, we develop gradually the idea that we cannot think about contents without taking into account missions, organizations, geographical contexts and actors. This position is contrary to that which is largely shared by the international forums: the exemplary nature and spread (Billé, 2009) of some “Best Practices”.

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CONTEMPORARY SCIENCE EDUCATION RESEARCH: INTERNATIONAL PERSPECTIVES

This book includes a collection of papers on the following topics:

The Nature of Scientific Content

Structure and essence of scientific content, how scientific content differs from other contents; visualization, metaphors, models, modeling, analogies, simulations, and animations in science and their use in science education

History, Philosophy and Sociology of Science

Historical, philosophical and social issues of science, nature of science, and epistemology of science as they are related to science education

Informal-Outdoor Science Education

Developing and evaluating the impact of programs and experiences outside the classroom by institutions and organizations other than schools (i.e. museums, science and technology centers, zoos and botanical gardens, scientific research laboratories, and outreach centers) and learning experiences through mass media (in print, film, broadcast, electronic, etc.)

Science Curriculum and Evaluation

Curriculum development, reform, implementation, dissemination and evaluation, and international comparison studies such as TIMSS, PISA, ROSE; evaluation of schools and institutions

Altogether, these contemporary scholarly works, coming from countries around the world, are successfully displaying the current tendencies and applied methodologies in the above mentioned areas of science education. By including them in such a volume we open them for further scrutiny to better our own doings in the field.