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EDITORIAL

M. Fatih Taşar, Associate Editor
Gazi Üniversitesi, Ankara, TURKEY

Dear members of EURASIA family,

Today I had to learn with deep sorrow that the eminent mathematician and physicist professor Erdal İnönü passed away at the age of 81 on October 31st, 2007 at around GMT +2, 05:00 PM. For the last couple of years he was being treated for leukemia.

He was born in Ankara on June 6th, 1926. After having his bachelor's degree in physics from Ankara University he continued his graduate studies at Caltech where he earned his master's and PhD degrees. Between 1964 and 1974 he served at Middle East Technical University in Ankara as a professor of theoretical physics, department chair, dean, and rector. Then he moved to Istanbul to join the faculty of Boğaziçi University where he served as department chair and dean also. Additionally, he contributed to the foundation of The Scientific and Technological Research Council of Turkey in 1963 and was honored the Science Award in 1974. He served as a member of both NATO Science Committee and the Executive Board of UNESCO.

Professor İnönü received the Wigner medal in 2004 and after late Feza Gürsey has become the second Turkish scientist to receive it. Lately he gave more emphasis on the history of science in Turkey during both the Republican era and the Ottoman period. He was affiliated with Sabancı University until today.

Professor İnönü had a unique sense of humor. It is told that when returning from movies a journalist comes across with him and tells him that they weren't able to see him at the movies in recent times. İnönü replies "indeed it is very much dark inside."

At this point I would like to extend our condolences and sympathies to his family, close friends, and students.

***

On a separate note, as you will probably recall in the last editorial I clued that there would be a new section in EURASIA starting with this very issue: **Conversation/Interview**. The first guest of this section is Professor Norman G. Lederman of Illinois Institute of Technology. I had a chat with him in Malmö, Sweden on August 25th, 2007 during the ESERA Conference. The title of our conversation is "*Norman G. Lederman and the Past, Present and Future of the Nature of Science Research.*"

In the coming issues I am aiming to publish such conversations and/or interviews. Those who are planning to do anything of this kind should consult me first. The format does not necessarily have to follow a strictly limited and/or definite one. Creative ideas are always welcome. However, I need to emphasize that EURASIA is also going to publish the audio or whenever possible video file of the conversation/interview along with the transcription. Appropriate picture(s) to be taken during the interaction can be used to enrich the content.

In the coming issues/years I am aiming to utilize and give a way to the appropriate usage of the media files in regular research papers. I hope that EURASIA will play a pioneering role in that. I strongly believe that having the media files along with their transcription will definitely enhance the meaning of our texts. We are all familiar with the saying: "a picture is worth a thousand words." Hence, I am saying that one minute of a video clip is worth ten thousand words! So, why not utilize them?

Surely, I am aware of the legal issues surrounding using pictures/videos of pupils publicly in various countries/states. Therefore, I wanted to start with ourselves until a list of guidelines are set and becomes acceptable for internet publishing.

I will rely on your expertise and contributions in that endeavor. We can use EURASIA as a platform to discuss such matters in the coming months. So, if you have ideas please send them to us to be published in a column of "Letters to the Editor."

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How Do We Help Students Build Beliefs That Allow Them to Avoid Critical Learning Barriers and Develop A Deep Understanding of Geology?

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Students hold a surprising number of ideas about the Earth's structure and process. This paper begins with a discussion on the nature of understanding in the conceptually confined domain of geosciences. There then follows a report on a study of the ideas about a range of concepts relating to "crystals", "volcanoes", "rocks", and the "Earth", held by eighth-grade students (13-14 years) in one middle school. Such patterns, described here as "alternative frameworks", can be used to inform our understanding of students' learning in earth science. If these alternative frameworks are not taken into consideration, they can represent "critical barriers" to learning in this domain in addition to other barriers identified in this research. The aim of this paper is to relate the students' alternative frameworks, the "critical barriers" that have been spotted and the possibilities of overcoming them. Several different recruitment strategies were used to collect data in order to get to know the students' alternative frameworks. The methodology of this study is based on two researches: a test of the Q-Sort and a paper–pencil test. Based on the results, some suggestions to help teachers and students avoid critical barriers that may be difficult to overcome later in their geological education are presented.

Keywords: Geosciences, Teaching, Learning, Barriers to Learning

INTRODUCTION

At the middle school level, the French National Science Education Standards require children to develop a scientific understanding of the Earth's materials and, logically therefore, of the Earth's structure that provides the context for such an understanding, and emphasize the importance of applying teaching methods that meaningfully engage students in earth sciences learning (B.O.E.N, 2005). In seeking to support children's understanding in this domain, constructivist theories of learning and teaching provide a model which highlights the importance of children's existing ideas as the focus for conceptual change. However, rather than address such ideas in isolation, research has suggested that a focus on the underlying frameworks or structures within which such ideas are embedded may prove more productive (Vosniadou & Brewer, 1992).

The goal of this study was to argue that children's ideas about concepts such as "crystal", "volcano", "rock", and "Earth", reveal broader patterns of understanding that provide a more informative guide for teachers to address than the consideration of such ideas in isolation. To do this, teachers would need to know not only what constitutes understanding in earth science, but also, if they are to employ a constructivist model of teaching and learning, how such underlying patterns of understanding can be identified and used to target strategies that better facilitate learning in this domain.

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STUDENTS' UNDERSTANDING OF GEOLOGICAL CONCEPTS

For the last three decades, there has been an increasing awareness of the importance of the variation among the ways students conceptualize and think about the phenomena they encounter in either science classes or in daily life (Gilbert & Watts, 1983; Driver et al. 1985; Osborne & Freyberg, 1985). Researchers in many countries have tried to respond to many important questions related to students' existing ideas, what the source of these ideas might be, how extensive they are, why they are so resistant to instruction, and what teachers can do to facilitate conceptual change (Astolfi, 1985; Driver & Bell, 1986; DeVecchi, 1994). Although extensive efforts have been made in physics, biology, and chemistry to identify students' existing ideas, research of existing ideas in the earth sciences has been more limited.

Understanding of the geological aspect of earth science is complex, not only because of the abstract nature of a number of its key foundation concepts (Ault, 1984), but also because it is multi-dimensional and hierarchical. In addition to understanding specific concepts such as "rock", "volcano", "magma", "crystal" or "Earth", it is also necessary to understand three different groups (structure, materials and processes) within which relevant individual concepts are embedded. For instance, a knowledge of the concept group relating to the Earth's structure would incorporate a knowledge of specific concepts such as "rock" and "bedrock", whereas a knowledge of the concept group processes would include knowledge of specific concepts such as "rock formation". This is essential for an understanding of the relationship among the three concept groups, which provides a holistic view of how the earth functions as a dynamics system: a process–product view of rocks described and classified on the basis of their origin within the rock cycle (Duff, 1993). Moreover, there are many kinds of understandings. One may provide the basis for a description of an event, whereas another does more and enables an explanation (Giordan & DeVecchi, 1987; Astolfi & Peterfalvi, 1993). Both descriptive and explanatory understanding come together in earth science to provide knowledge of essential attributes and link concepts with each other to structure scientific perception: a descriptive understanding of how these elements interact as part of a process-product-based system. In planning to support children's understanding in earth science, it is important for teachers to be informed not only of the content of children's prior knowledge, but also of the kinds of understanding such knowledge represents.

Research in Europe and the US has given us a detailed picture of children's understanding of the geological aspects of earth science:

- The Earth's materials: minerals and rocks (Happs, 1982, 1985; Dove, 1998; Ford, 2005);
- The Earth's Structure (Lillo, 1994; Sharp et al. 1995; Blake, 2005);
- The Earth's processes: mountains, volcanoes, earthquakes, weathering and erosion, and geological time (Bezzi & Happs 1994; Sharp et al. 1995; Russell et al. 1993)
- Geological time (Hume, 1978; Ault, 1982; Trend, 1998).

These studies confirm that children develop their own, mostly non-scientific, understanding of earth science concepts before instruction, and describe and interpret these in everyday terms that are familiar to them. In addition, they have shown not only how generally limited children's understanding of the Earth's structure, processes and materials is, but how different their conceptions are from those of earth scientists. Importantly, key "critical barriers" to children developing a scientific understanding in this domain have been identified (Ault, 1982; Bezzi & Happs 1994; Trend, 1998):

- Geological time;
- Large scale patterns in the environment and the physical changes they represent;
- Bedrock: its existence, scale and layering.

Research of children's existing ideas arises from a constructivist view of science learning (Driver & Bell, 1986; Vosniadou, & Brewer, 1992; Vosniadou, 1994). This view of knowledge posits that learning is a complex process in which instructional experiences interact with the learner's existing beliefs, experiences, and knowledge. Student learning always depends on what students bring to the classroom as well as the experiences they have there. If learners already have theories of how the world works, instruction must be structured to acknowledge and challenge these children's existing ideas (Osborne & Wittrock, 1985). Among a number of researchers (Vosniadou & Brewer, 1992; Vosniadou, 1994; Schnotz et al. 1999) there appears to be a general consensus over a number of important characteristics relating to these existing ideas, in that they are:

- Based on the individual's prior knowledge and experience of the world around them, which develops from birth;
- Personally-constructed views about the physical world which act as personal theoretical lenses and, as such, determine what, for us, counts as observation and what counts as inference;

- Different from the accepted scientific view of the same concept; and
- Resistant to change.

Opinion differs, however, as to whether these various scientific conceptions constructed in students' minds are to be referred to as "misconceptions", "preconceptions", "alternative frameworks", "children's science", or "preconceived notions" (Westerback et al. 1985; Marques & Thompson, 1997; Kusnick, 2002). If these terms are examined for similarities, they have almost the same meaning. In a comprehensive view of the field, Schnotz et al. (1999) defines alternative frameworks, which represent the transformation of students' ideas into knowledge structures or scaffolds determined by researchers. Consistent with this usage, in this paper, the term "alternative frameworks" is used to describe children's ideas about specific earth science concepts such as "crystal", "volcano", "rock", and "Earth", which is different from or inconsistent with the accepted scientific definition.

PURPOSE OF THE RESEARCH

Previous studies have tented to focus more on the investigation of single (or small clusters of) concepts such as rock, mountains or underground held by large numbers of children, rather than on the simultaneous consideration of a range of ideas about the Earth held by individual children and whether these reveal broader underlying patterns of understanding. This paper reports on a study that investigated the children's ideas about the concepts groups (structure and processes) such as "crystal", "volcano", "rock", and "Earth", held by individual children from eighth grade in one middle school in north-west France.

The research was constructed around the following three basic research questions:

- What are the students' alternative frameworks of these four concepts?
- By what means do they create critical barriers to learning?
- Under what conditions could these critical barriers be overcome?

Volcano, rock and the Earth are designated objects commonly studied in the eighth-grade curriculum and are explained in detail. The concept of crystal, on the other hand, is not presented in the same way and is seldom defined in the textbooks currently used in French middle schools. However, the crystal concept must be introduced at the same time as the study of the origin of rocks; if not, this study risks being reduced to a mere presentation of facts (Happs, 1982).

METHOD

The sample

The sample consisted of 120 eighth-grade students. A total of 120 students (13-14 years), of mixed ability and gender from a non-selective "fringe" inner-city middle school in north-west France were involved in the study.

Students' alternative frameworks were collected in the middle of the first term after the introductory lessons to geology and the study of the origin of a sedimentary rock observed during a field trip. The students had not yet studied the themes relative to the internal activity of the Earth (volcanism, seism …).

Instruments and data-collection procedure

In this study, several different recruitment strategies were used to collect data in order to learn about the students' alternative frameworks. The methodology of the study comprises two research: a Q-Sort test and a paper–pencil test.

The Q-Sort test was based on the format developed by Vérin and Peterfalvi (1985), which uses words to be put in relation with three concepts: Crystal, Volcano, Earth (see Appendix A). These words were chosen from a list of words collectively prepared with the geosciences educators in the middle school where the research was done. As these educators indicated during our inquiry, the chosen words had been frequently used by students in their previous assessments.

The paper-pencil test was used to provide more in-depth understanding of particular aspects of the Earth's structure and the Earth's functions. The paper–pencil test included three sections, which comprised drawings and open–ended questions (see Appendix B). These sections consisted of:

- A section on the students' advanced explanation concerning the release or the end of an eruption and the manner in which they portray a volcano (above-ground portion and underground portion);
- A question on the manner of portraying the interior of a crystal and a question asking the students to define a crystal;
- A question concerning the schematization of the relationships between volcanoes and the structure of the Earth. The children were asked to explain the global spread of volcanoes on the surface of the Earth and, in doing this, to represent the latter in cross- section. To ensure that the children understood this task and were able to conceptualise what a cross-sectional drawing

represented, an analogy with the inside of a pear was used. A pear was cut in half, and the children were asked to discuss, and then draw, a cross-section through the pear, labelling the parts.

The questions were selected from previous studies by different researchers (e.g., Bezzi & Happs 1994; Lillo 1994; Ford, 2005) and then adapted to a French context. The questions were phrased in such a way that they could be easily understood by the respondents. In addition, the questions were given to a group of eighth-grade students and teachers for comments on their readability. This process could better suit the question to the context.

A group consisting of geosciences educators was established to examine the validity and readability of the test. The group agreed that the questions could be used for the study's purpose. The group also commented that the question topics were within the range of the topics in the curriculum. In addition, the test questions selected from the related literature were validated in those studies. To examine how students visualise these concepts, we asked them to make drawings to explain their answers. Children enjoy drawing and are able to use drawings to communicate the identifiable features of objects they have been asked to draw (Haynes et al. 1994), although caution is needed when using drawings to represent children's understanding as what is not drawn does not necessarily imply the absence of these mental structures (Newton & Newton, 1992). Data from the drawings were triangulated with information from other probes to provide a more complete "picture" of a child's understanding. This kind of instrument has been used by many researchers in the related literature (e.g., Happs, 1982, 1985; Lillo 1994; Blake, 2005).

The test was administered to one sample (120 students from Grade 8) over a period of two school days. Each section was completed in 30 minutes. The sample group were encouraged to respond to all questions to the best of their ability because their written explanations were very important to identify alternative frameworks.

Some researchers such as Kusnick (2002), Blake (2005), Ford (2005), preferred using numerical scores in their assessment and analysis procedure for statistical purposes. However, making a statistical analysis was not our aim. Rather, bearing in mind that students' errors do not consist of simple aberrations (Schnotz et al. 1999), we wanted to pinpoint the variety of students' identified alternative frameworks that represented "critical barriers" to children developing a scientific understanding in this domain. We defined and discussed in detail the most prevalent key "critical barriers" and made suggestions as to the origin of same in order to help teachers and students avoid these "critical barriers".

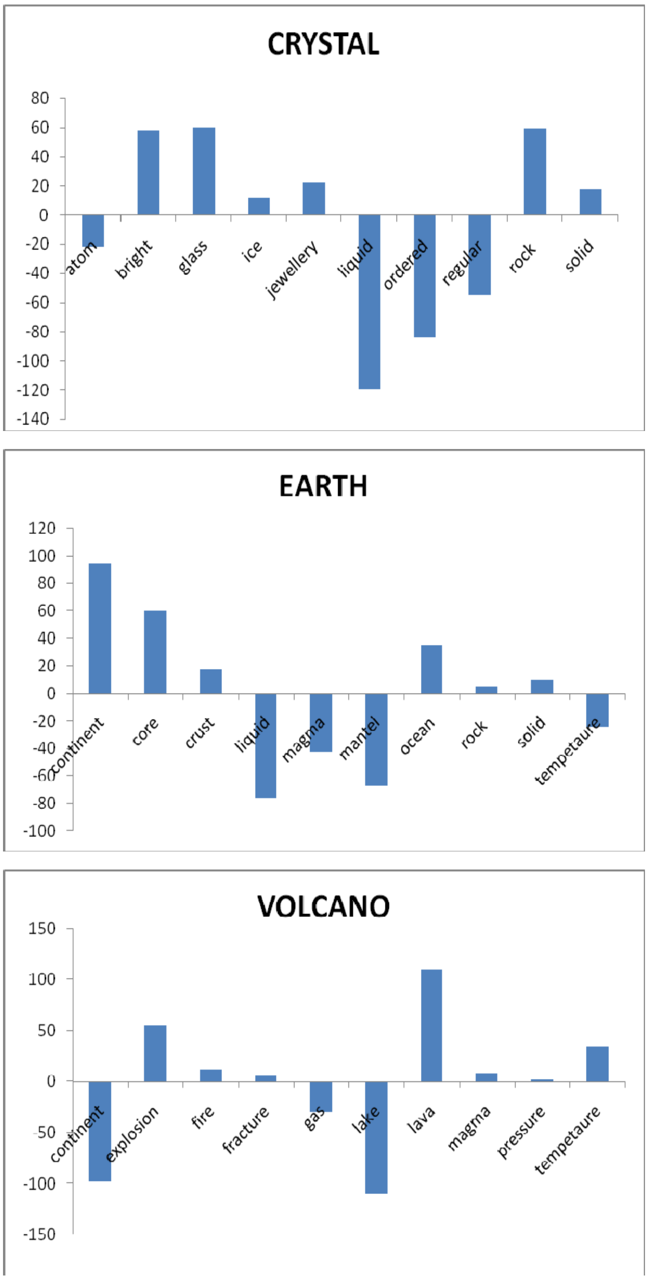

Figure 1. The answers given to of the Q-Sort test by 120 students.

RESULTS

Result from the application of the Q Sort test

In Figure 1 the values appear in an ordinate representation that corresponds to the strength of the agreement or rejection. These values were calculated in the following manner: a coefficient of "+2", "+1", "-1", and "-2" was given to each word and corresponded to "strongly associated", "roughly associated", "roughly rejected", or "strongly rejected", respectively. If they were neither specially associated nor rejected, the coefficient used was "0".

The advantage of such a presentation with positive and negative values is to be able to facilitate the visualisation of the distinctions between the words that are in agreement with the students' ideas and those that are rejected.The data are presented by concept.
These results call for the following comments:

Crystal

The "crystal" concept reminds many students of "jewellery" or of the idea of something "shiny", even "glass" (but then again, who has not seen or heard people talk about crystal glasses?). The same student approaches have also been found in a number of similar studies (Happs, 1982; Russell, 1993; Blake, 2005). The crystal-"rock" association is also frequent; this can be explained by the fact that this test was taken after the study of different crystalline rocks in the context of an introduction to geology. The crystal concept has sometimes been used as a replacement for the "grains" concept. "Solidity" is another characteristic that students associate with crystal (Happs, 1982; Vérin & Peterfalvi, 1985).

On the other hand, four words are strongly rejected; namely, "liquid", "regular", "atom" and "order". Similar to Happ's (1982), Vérin and Peterfalvi (1985) and Westerback et al. (1985, 1991) analysis in their articles, the rejection of the word liquid is apparently linked to the fact that the known examples of crystals are in a solid state. The rejection of the word "atom" is apparently linked to the fact that this word is not well known by students of this level, as they do not study it in physical science in the eighth-grade, and the cultural context of these students does not allow them to study this word. In short as eighth-grade students have rarely observed crystals, at this point in the year; how could they detect any regularity? Finally the idea of order, has no other echo than one of classifying without any connection to the idea of a particular organisational pattern.

Volcano

Regarding the idea of a "volcano", it is principally linked to the idea of "lava", "heat" and "explosion". This is similar to findings by Bezzi and Happs (1994), Sharp et al. (1995) and Marques and Thompson (1997). These associations occur without any commentary. It's the phenomenological aspect that is retained. Even though this test was given before any film presentation on volcanism, as many eighth-grade students had already seen short films on the subject on television, would this be due only to televised documentaries? A volcano is a mountain that gives off heat, produces explosions and throws out lava. The volcano-"fire" association is also quite frequent. It shows the impact of certain images in the description. Therefore, when we later asked the students to indicate the words that they immediately associated with the images seen after viewing a short film on a lava flow, they indicated the word embers as a characteristic key word for volcano. This association can also be obvious in the speeches of certain scientific popularisers under the title of metaphor (see Tazieff & Willemin (1994) in the program, The Fire of the Earth – 3rd episode). It is reinforced by the colour of the lava; the flames that we see as trees and dwellings burn on contact with a lava flow.

Similar to findings by Lillo (1994) and Sharp et al. (1995), the idea of "magma" is rarely linked to that of a volcano but this non-association is very unequal in the students' minds. Certain students confirm that they do not know this word. In contrast, other students remarked the presence of magma as the principal constituent of the globe by pointing out that they had heard of it in geography lessons. An inquiry with the teachers of this subject in the middle school where we did our research indicated that the word was generally cited in their classes. This signifies that the word magma was not integrated and remained at an anecdotal level.

On the contrary, the idea of "gas" and, to a lesser extent, that of "pressure" is hardly ever associated with that of a volcano. This is probably due to the absence of questioning on the mechanism of volcanic eruptions (Bezzi & Happs, 1994; Sharp et al. 1995), and for two related reasons:

- Gas and pressure are two concepts that will be broached later on in schooling;
- At this period in the school year, the concept of gas evokes a substance contained in a recipient (candy, candy box for example) and not a state of the material (Stavy, 1988); the concept of pressure is more in relation with pneumatics or meteorology than with the idea of movement (Abraham et al. 1994).

The apparent rejection of the words "lake" and "continent", is maybe due to the fact that these two words are less related to the eruptive aspect of volcanoes; hence, their lesser attraction.

The Earth

The results concerning the ideas related to the concept of the "Earth" indicate that this concept designates an entity difficult to specify: a globe formed of oceans and continents, with a core in its centre (an image of a cherry or a peach). Similar to Vosniadou and Brewer (1992), Lillo (1994), Marques and Thompson (1997) and Blake (2005), analysis in their articles, students principally make associations with directly-observable elements ("ocean", "continent", "rock"). We can therefore understand that "liquid" is an answer rarely associated with the Earth, even if it appears to contradict the answers of other questions of the paper-pencil test. If the interior of the Globe constitutes a liquid, it is invisible from the exterior; if it is a question of oceans or of seas, many students do not know that they form the largest surface of the globe. On the other hand, students reject "magma" and "mantle", as they are unequally known to them, not as the opposite of the concept of the Earth, but as non-associated answers to this concept.

The intention of such a Q Sort test is to have a rapid image of some associations among three key concepts of the curriculum and the ideas of a student population. However this test presents a few limits:

- The possible associations are limited;
- Certain words were unknown to the students;
- A part of the variation of the results comes from schooling differences. Certain students get a mental block when faced with such a test asking them to engage notions not yet officially broached in lessons; they feel vulnerable. Other students are not affected by this aspect, either because they consider this lack of knowledge natural, or because their past schooling has taught them not to be ashamed of their gaps (Vérin & Peterfalvi, 1985);
- Certain students do not understand the function of the test. They reject certain unknown words, not because they do not associate them with the key concept, but because they do not know them.

RESULTS FROM THE PAPER–PENCIL TEST

The first section: From lava to rock or the liquid-solid passage

From a valve-volcano to an inactive dry-volcano

The first two questions (see Appendix B) allow us to find out the way in which students imagine the interior of the Earth underneath the volcanoes, and could be subtitled: "Where do the lava (and the other products rejected by the volcano) come from?" The resultant representations are outlined below:

1. The drawings of volcanoes in relation with the interior of the Earth (the most numerous); "the interior of the Earth is liquid just as the lava is liquid". Two subsets can be spotted:

a. Similar to findings by Lillo (1994) and Sharp et al. (1995), volcanoes, generally in relation to an immense lake of underground lava (a conception recapturing that which prevailed at the beginning of the 20th Century at a scientific level (Gohau, 1987)): "lava comes from the Earth's magma (drawn just under the ground); it comes from underground rocks; lava is a molten rock coming from a reserve";

b. Similar to findings by Blake (2005), volcanoes in relation to the core (this being, at least a part of it, considered as a liquid, does not give the students any problems): "the lava comes from the core of the Earth that propels it outside; the lava comes from the heart of the Earth".

2. The drawings (very few) of volcanoes possessing a lava lake in the interior of the cone (a volcano like Mount Nyiragongo); whose origin is precise: "the lava comes from the bottom of the volcano" (an arrow indicates the lava lake drawn in the cone). The eruption is therefore just a simple overflow of lava in the manner in which milk overflows in a pan when we forget it on the hob: "lava is a molten rock coming from a volcano that overflows" (associated with a drawing of a cone containing lava).

3. Similar to findings by Happs (1982), a few descriptions of inactive dry volcanoes: they expel rocks that are formed on the walls of the volcano. By anticipating the following paragraph, the students do not ask themselves the question about the solidification of lava because, for them, the volcanic rock already exists.

Hardening or crystallization?

The third question (see Appendix B) was designed to know how the students foresee the liquid-solid passage, as it is, along with others, the object of the eighth-grade lessons. Three types of answers were produced:

1. The rejected basalt comes from the walls of the volcano (to be put in relation with the inactive dry volcanoes). We already mentioned the problem arising from this type of answer.

2. It is the cooling process that causes the solidification of the lava, the term solidification sometimes being replaced by that of hardening. The lava hardens as a mass…: "the rocks are formed with the lava that has cooled down on contact with the air; these rocks are created by the lava that hardens on contact with the air; it is the lava that has solidified". This type of response is similar to those found in other research on children's thinking (e.g., Westerback et al. 1991; Sharp et al. 1995; Ford, 2005).

3. It is by the drying process that the liquid is transformed into a solid: "the red (a volcanic bomb) formed itself by using bits of earth that rolled into the lava and then dried; they (the volcanic rocks) dried on the earth after an eruption; when lava dries it is in a block".

Nevertheless, it must be added that, in the last two types of answers, the phenocrysts of olivine and pyroxene in the rocks are compared to small stones, bits of earth or dust that the lava picked up on the way: "these heavy rocks are full of holes; there are bits of black and yellow stones". The same student responses have also been found in a number of similar studies (Happs, 1982; Russell et al. 1993; Dove, 1998). Therefore, these elements are not directly linked to the formation of volcanic rock: "while forming (the basalt), it picked up small stones on the way, which then integrated themselves into the rock".

The eruption mechanism

Questions 4 and 5 (see Appendix B) should allow us to find out what knowledge is mobilised by the students in their answers.

Similar to findings by Bezzi and Happs (1994), some sample examples are given below:

"The lava comes up because there is an eruption";

"The lava comes up because there is too much lava underground; therefore, not enough room and it overflows (the excess of lava comes from the ground or underground that melts from the heat)";

"The growing heat pushes the lava up";

"The lava is expelled by the gases";

"Two plates separate".

The end of the eruption is often simply the opposite phenomenon of that which caused the lava to rise.

After the questionnaire, similar to findings by Ault (1982), Happs (1982), Westerback et al. (1985), Bezzi and Happs (1994), Sharp et al. (1995), Trend (1998), it will be possible to formulate four types of students' alternative frameworks relative to the formation of volcanic rocks:

1. The transformation of lava into a rock is a simple phenomenon, even passive, we could say, within which the material becomes a block by solidifying, drying, freezing. The crystals do not exist as a result of crystallisation, as those that are visible are considered as dust. Crystal itself is not different from glass, meaning that everything that is solid has a resemblance;
2. A rock has no history because it has always been solid (or at least some of its constituents have);
3. Heat causes the lava to rise;
4. Lava rises because there is an eruption.

The second section: Crystal: A solid constituted of particles packed in a regularly ordered, repeating pattern extending in all three spatial dimensions or a composite object?

After analysis of the students' ideas relative to volcanism, in the second section, the objective was to get an idea of how they portrayed the structure of crystals (see Appendix B).

We must specify that these objects, as well as their chemical composition had already been broached at the beginning of the geology course and the particular structure of the matter had been studied in physics classes. Nevertheless, these notions are complex for eighth-graders, and there is a risk that this question may reinforce false ideas in the students' mind about the notion of a "molecule". On the other hand, the students had no knowledge whatsoever of the crystalline structure of ionic constituents. The principal objective of this question was to find out how they imagined the interior of two different crystals, which would explain the differences of form, and in particular, if they re-employed the idea of molecules (as particles that compose the material), by associating it with a particular disposition.

The analysis of the students' productions shows two principal types of answers (see figure 2).

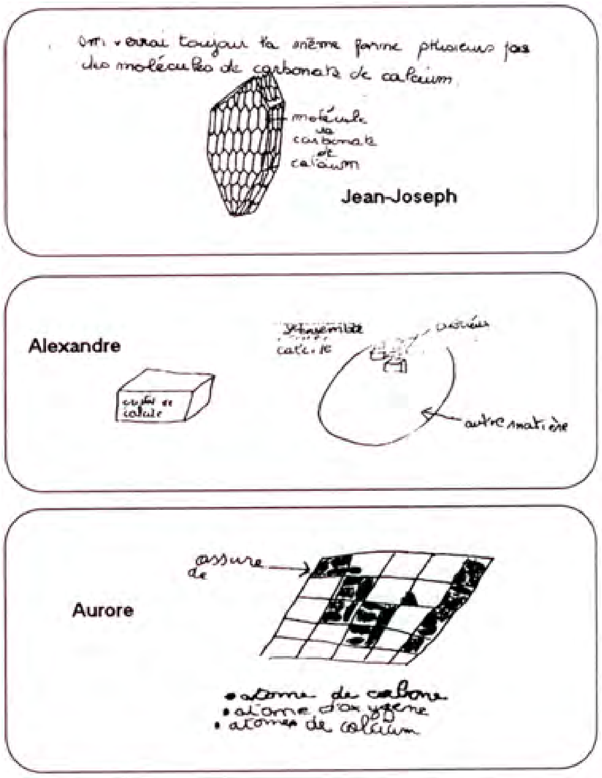

Figure 2. Students' answers indicating the structures of aragonite and calcite crystals.

- Certain students, like Jean, portrayed each crystal as though it were composed of small crystals having the same form as the macroscopic crystal. For these students, the macroscopic characteristics that we can observe are represented through a model of the crystal. A variant of the system (Alexandre) is the representation of the crystal as a whole, made of separate small crystals, sometimes by an intercrystalline material qualified as "another material".
- Other students, like Aurore, re-employ the idea that crystals consist of an assembly of small carbon, oxygen and calcium particles. Each assembly constitutes a motive, and the crystal appears as a regular repetition of motives.

The basic barriers to understanding (Ault, 1982) found are apparently the continuity between the macroscopic and the microscopic (cited as primitive perception in Vérin & Peterfalvi,1985 and Astolfi & Peterfalvi, 1993).

After research of the characteristics of a crystal in the Q-Sort test and previous question, here are a few of the students' answers to the question: "What is a crystal?" (see Appendix B) They show the resistances of preliminary conceptions.

"A crystal is a rock that can be transparent. "A crystal can have many colours". "A crystal is a rock that is usable in commerce";

"A crystal is a shiny material and has a geometric form. It, itself, has a geometric form. As soon as we break it, the pieces that form it still have the same geometric form as in the beginning";

"Crystal has a geometric form. It is shiny; we can see what is in the interior. If we break it, it will still have the same form. It must not be forgotten that crystal is a transparent stone".

There is an obvious juxtaposition of acquired concepts and old ideas (non-scientific, incomplete) that reside and make it difficult to select the characteristic traits of crystal.

The third section: The Earth: a globe with a peach structure

In the Third Section, the children were asked to explain the global spread of volcanoes on the surface of the Earth and, in doing this, to represent the latter in cross-sections (see figure 3).

The graphic representations done by the students are supplemental to the Q-Sort test results. There is an obvious coherence in the "alternative frameworks" raised. As found in previous studies (Lillo, 1994; Marques & Thompson, 1997; Blake, 2005), the terrestrial globe often appears to be composed of three parts: "the crust", "the core", and in between the two, a zone sometimes called "the mantle".

- The core is either a ball of fire (Marianne), or a reserve of lava (Marianne, Didier, Dimitri).
- The liquid mantle either consists of magma or lava, or of water.
- The crust's role is either to "protect" the Earth or to "prevent" the lava from leaking out.

Similar to the findings of Bezzi and Happs (1994), Lillo (1994), Sharp et al. (1995) and Blake (2005), volcanoes are in relation either with the core or with the mantle, the liquid nature of which is preponderant. The model of a "pressure-cooker", proposed by Didier, is interesting in this sense as the idea of a necessary pressure for the eruption is already present.

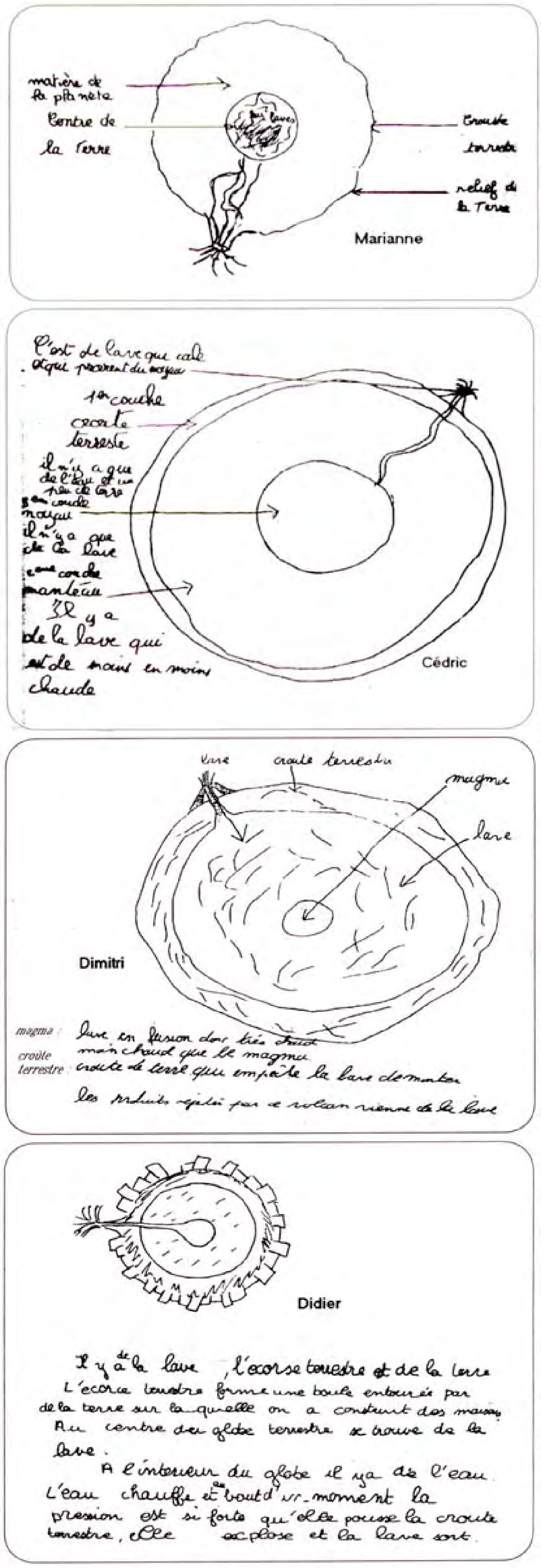

Figure 3. Examples of the students' drawings of the Earth's cross-section.

In addition, he added this commentary under his drawing: "In the interior of the Earth there is water. The water heats up and after a while the pressure is so strong that it pushes the terrestrial crust; it explodes and the lava comes out". This may be explained by the fact that this student has tried to describe volcanoes as a security valve of the Earth (see figure 3).

One of the barriers to learning that appears is the idea of the liquidity of the interior of the Earth, an idea reinforced in all the questionnaires in this study.

DISCUSSION: ANALYSIS OF BARRIERS LINKED TO STUDENTS' ALTERNATIVE FRAMEWORKS

The diverse alternative conceptions may basically be considered in two different ways:

- Either they constitute simple errors, linked to structural or abstract shortcomings, or even a lack of knowledge of basic concepts that we could correct with appropriate exercises (Astolfi & Peterfalvi, 1993; Vosniadou, 1994);
- Or they are critical barriers to learning, as they create ways of thinking that are not adapted to the situation. A change of style with an epistemological rupture is therefore necessary (Ault, 1982; Vosniadou & Brewer, 1992; Trend, 1998).

We must therefore deal with the barrier to learning in a manner that will enable the students to spot the difference between their own explanatory system and the new one, and suit it to their needs. We agree with Schnotz et al. (1999) when he writes "a child can only feel secure if he is certain of having understood what disconcerted him beforehand". To which more general and specific barriers to learning do these students' alternative frameworks correspond?

General barriers

"A student's alternative framework is an explanation or an interpretation, which, by its simplicity, asserts itself as evidence and prevents him from asking himself questions that would speed up the knowledge" (Driver & Bell, 1986). This description reminds us that the students' alternative frameworks are also critical barriers preventing the acquisition of a real motivation to learning. By motivation we mean "cognitive motivation" and not just a mere attraction. As Ault (1982), Astolfi and Peterfalvi (1993), Vosniadou (1994), Trend (1998) have suggested, overcoming identified barriers to learning is "the conceptual issue of learning".

These barriers are rarely isolated but often interact (Astolfi & Peterfalvi, 1993; Vosniadou, 1994; Blake, 2005), which means that they do not correspond to a single type of specific barrier, but to more general barriers. Dealing with such barriers can not be done simply and directly through a single geology lesson, because they are deeply rooted in the student's mind and this narrows the possibilities of eliminating them (Vosniadou & Brewer, 1992; Vosniadou, 1994; Trend, 1998). These barriers must be dealt with on different occasions, not only in biology-geology lessons, but also in other subjects (Astolfi & Peterfalvi, 1993; Vosniadou, 1994). We are therefore far from the very simple idea that a good explanation would permit the student to "rectify" his error.

The general barriers to learning that have been identified are of many natures, namely:

- Tautological barrier: The student is happy to repeat what he has seen, sometimes by integrating an explanatory link-word (because, as…) into his "explanation" (Astolfi & Peterfalvi, 1993): "The lava climbs up because the volcano erupts"; "A rock is a stone"; "A rock, a pebble…"
- Verbal barrier: The student finds it difficult to change the semantic style (Happs, 1982; Vosniadou & Brewer, 1992; Schnotz et al. 1999): "Glass is a fragile material, solid is the opposite of fragile". Because of this, students can not visualize a crystal as being solid.
- Artificial barrier: The student takes in what he observes as a result of man's actions, this then serves as his explanation (Happs, 1982; Kusnick, 2002; Ford, 2005): "The form of crystals (automorphes) is the result of cutting and is not natural"; "A rock is a decorative object"; "A crystal is a jewel".
- Absence of a causality relationship between the phenomena: The student is therefore happy to establish, the best he can, modern-day relationships (Vosniadou & Brewer, 1992; Sharp et al. 1995): "When there is an earthquake the volcano erupts".

Besides these barriers identified there are also those linked to non-adapted ways of thinking. For example; the categorical way of thinking is only a barrier to learning when it prevents the student from progressing (Astolfi, 1985; Driver & Bell, 1986; Schnotz et al. 1999). Just thinking of the material as three criteria classified as "solid", "liquid" or "gas" is not a problem in itself; it only becomes one when the student is not able to overcome these criteria in order to understand the issues relating to a vitreous or crystallised structure.

It is the same thing with primal perception. The students will try to interpret everything from what they see without thinking about changing the style (Happs, 1982; Astolfi, 1985; Schnotz et al. 1999). For these reasons, the following ideas can play the role of a barrier to learning:

"A crystal is composed of microscopic crystals";

"A crystal is a shiny material";

"A rock is a big stone and is coherent (meaning not composed of elements)";

"Crystallisation is a simple mass formation, drying process, i.e. green grains (in basalt) are dust, blocks of rock that the lava picked up on its way";

"A rock exists and has always existed";

"A solid rock can not be deformed";

"The interior of the Earth is a big liquid pocket".

These types of barriers to learning are not particular only to earth sciences, but can also be seen in different forms in other branches of sciences, as well (Gilbert & Watts, 1983; Driver et al. 1985).

Specific barriers: Students' alternative frameworks, a matter of cognitive functioning

For the barrier to learning to be overcome, the student must be ready to leave his ideas behind (Ault, 1982; DeVecchi, 1994; Blake, 2005). It is essential to know what students' alternative frameworks explain and what these alternative frameworks prevent them from understanding, as Astolfi and Peterfalvi (1993), Vosniadou (1994) and Schnotz et al. (1999) proposed. This work was carried out based on a few specific barriers encountered at different moments in this study.

Similar to findings by many researchers in the related literature (e.g., Bezzi & Happs, 1994; Lillo, 1994; Trend, 1998), in this study, the specific barriers to learning emphasised by these few students' productions can be grouped into three main generalisations.

- Crystals do not correspond to a precise organisation of the material;
- A rock does not have a history;
- The Earth has a liquid interior.

These three generalisations appear in one form or another through the lessons. Therefore, during the lesson where basalt was studied (within the context of the first questionnaire of the paper-pencil test on volcanism), the idea that the visible crystals in the rock are dust that the lava picked up on its way corresponds to the first barrier to learning as previously quoted. This enables these students to understand that the rock that they are observing is composed of a homogeneous mixture (the black part of the basalt) within which they see crystals (compared to dust) (Happs, 1982; Westerback et al. 1985; Russell et al. 1993). They therefore explain, in a few words, the way in which basalt is formed without this causing them a problem.

In the school textbooks (e.g., Tavernier, 2004; Périlleux & Thomas, 2005; Salviat & Desbeaux, 2005), a reflection of the teachers' way of functioning, this problem is presented in the form of a question:

- "How can the presence of crystal and glass in the same rock be explained?"
- "How have incandescent lava flows been able to give birth to this rock (basalt)? What are its characteristics?"
- "Do these observations allow for understanding how basalt is formed?"
- "What relationships can be established between the volcanic rock's structure and the two-timed rising of the magma?"

These questions are not real problems that put the students in a research situation, as they already have a solution. Furthermore, even though the description of basalt (black mixture and green dust) is inexact, we cannot say that the flowing lava does not pick up samples of the material present on the ground at that precise moment. This explanation will reinforce the students' alternative frameworks.

Nevertheless, for there to be a scientific problem, the students must realise that their explanatory system no longer functions (Gilbert & Watts, 1983; Astolfi & Peterfalvi, 1993; Vosniadou, 1994). Taking the chosen example, this explanation prevents the understanding that basalt, coming from the cooling down of the lava taken directly from a lava lake, is already composed of two categories of elements. The students' activity will therefore consist of the use of observations or experiments done in class to modify their point of view so as to eventually provoke a rupture with their original way of thinking (Westerback et al. 1985; DeVecchi, 1994; Vosniadou, 1994) and come to the idea that the crystals are formed by the slow cooling process of the lava. It will therefore be possible to put this in relation with the ordered structure of the particles. The advantage will be to finalise class work in relation to preliminary ideas.

This progress will require supplementary knowledge of the structure of the material and knowledge of crystal's properties in comparison with those of glass, for example.

Table 1 demonstrates the examples of an analysis of various barriers to learning by specifying the students' alternative frameworks, what the students' alternative frameworks help explain, what these alternative frameworks prevent the students from understanding, and the final idea that the teacher is seeking to teach.

The Concept: A conceptual level evolved in comparison to the student's alternative frameworks

Students always retain their first alternative frameworks regardless of what follows, and this is why they should learn how to use the right style at the right moment (Gilbert & Watts, 1983). Based on this supposition, finding the location of pertinent clues within the situation will therefore enable the student to correctly explain and anticipate the rest of the problem (Astolfi, 1985).

Table 1. Examples of an analysis of various barriers to learning

The students' alternative frameworks	*What the students' alternative frameworks help explain*	*What the students' alternative frameworks prevent them from understanding*	*The final idea that the teacher is seeking to teach.*
	The crystals do not correspond to a precise organisation of the material		
A (volcanic) rock is formed by drying up.	• The presence of crystals (considered as dust) is separated by glass	• A volcanic rock can be formed on the ocean bed as well.	• A volcanic rock might be formed at two stages: gradual cooling then rapid cooling.
Crystals are formed from small crystals with the same appearance from a macroscopic aspect.	• Different crystals have different structures. • Crystals have various planes. • Many crystals have a cleavage plane.	• Certain crystals have no cleavage.	• Crystals are made up of organized particles: this arrangement gives them their form.
Lava takes the form of a block as it cools. This is a passive phenomenon.	• Lava integrates the dust and small grains that it collects on its route within its fluid structure.	• Cooled liquid sulphur turns into crystal or glass. • There is crystal and glass in the rock which is formed upon the cooling of lava deep underground.	• The new structure of the lava that has become a rock by cooling occurs by the reorganization of particles.
	A rock does not have a history		
Rocks have existed forever.	• There are rocks dating back to ancient times. • Rocks have been used throughout history. • Rocks are inert objects.	• Not all the rocks have the same relative or absolute age.	• A rock belongs to history.
	The Earth has a liquid interior		
Lava comes from underground lakes forming the bedrock of the crust or Inside the Earth is a large pocket of magma.	• The materials ejected out of a volcano are liquid. • Continents drift independent of one another. • Plates change positions.	• In time, different lava combinations might be formed within the same volcano. • Different lava combinations might exist in volcanoes in different parts of the globe.	• Underground magma reservoirs exist independent of one another.
Lava comes from the core of the Earth.	• The core is liquid.	• Although the core is made up of iron nickel, volcanic rocks are composed of silicate.	• The formation of lava coming from magma starts from the crust or mantle.
Solid matter is not fluid.	• Rocks do not float on the surface of the Earth.	• The shapes of glaciers are distorted by the force of gravity. • The shape of glass may be changed without melting it. • Wax may change form without passing through a liquid phase.	• Under certain temperature and pressure conditions, rocks can change form without turning into a liquid state.
Matter is either solid, liquid or gas.	• Different types of matter can be classified according to their external appearances.	• Not all solid matter has a specific identity. • Although glass becomes liquid only after going through a phase of paste viscosity, crystals can directly become liquid without such an intermediary phase.	• Matter can be classified as having a crystallized and an amorphous structure.

Taking the example of the confusion "glass = amorphous structure in glass = window" (a confusion within which the choice of the semantic style used is wrong as the student has not thought about the structure of the material, but about the exterior aspect of the material). When the student must piece together the way a rock containing glass is formed in a conscientious manner or not, he must use another semantic style as noticing the process of glass being transformed into a window will not permit him to assemble this formation.

The student should verify what has changed in relation to what he was thinking (Vosniadou, 1994). This would mean, for the example above that he should be aware of the creation of a new style for the term "glass" and the necessity of using it when asked to think within the realms of geology.

We previously indicated that many eighth-grade students considered the olivine crystals, observed in basalt, to be "grains" coming from the wall of a volcano or picked up off the floor during the lava flow. The standard conceptual level which the teacher wants the student to grasp could be the following: "Macro-crystals are formed in the magmatic chamber" "Glass, which is a result of the lava quickly cooling down at the surface, then imprisons them". We can find such a conceptual level in many school textbooks (e.g., Tavernier, 2004; Périlleux & Thomas, 2005; Salviat & Desbeaux, 2005). This implies that these "grains" are expelled with the lava.

Yet the student runs the risk of not being able to differentiate between his original thought (that "olivine crystals are dust") and the superior conceptual level (expressed above). He will understand what he thinks is identical, knowing the presence of solid elements coming from the interior of the volcano, without seeing that, within his idea these elements have always existed, and therefore within the second conception they have a point of origin. The student is at a non-scientific level of the conception's structure (which would be a primitive stage of the concept) in comparison to the level of conception's structure envisaged by the teacher (which would be an evolved stage).

What relationships are possible between the critical barriers to learning and the geological objectives in the eighth grade?

A reminder of some of the aspects of the national curricula for France (B.O.E.N, 2005) related to magmatic rocks and the structure of the Earth:
"- A demonstration of the Earth's activity: the volcanism. Placement, structure of the rock, origin of the lava. Formation of the oceanic crust.

- The other manifestations of activity of the Globe: seism, deformation of the rocks.
- Continents, oceans, global structure.
- Global tectonics.
- The circulation of matter in the Globe: origin of metamorphic and magmatic rocks.
- Three rocks of a metamorphic series (layer, structure).
- A granite rock (layer, structure)".

If we situate the preceding analysis in relation to the titles above, the teacher's objective, in the eighth grade, could be to evolve the alternative frameworks of the students in relation to the three main types of barriers to learning that we have defined above:

- The crystals do not correspond to a precise structure of matter;
- A rock does not have a history;
- The Earth has a liquid interior.

Crystals do not correspond to a precise structure of matter

Students are often at a level that we have qualified as non-scientific. Crystals are not an object of geological study for them. They are a result of Man's work (shape, mould) (Happs, 1985; Dove, 1998); they are beautiful (shiny); and we find them in caves (Russell, 1993). It is the same thing with glass, which is nothing more than an industrial product, transparent, and used to fill windows while letting light in. It is necessary to remove this artificial idea from the student's mind.

Which conceptual level of glass does the teacher envisage? "A crystal is a solid formed by the slow cooling of a liquid or by precipitation from a solution". "Glass is a solid obtained by the rapid cooling of a liquid". A large margin separates the students' alternative frameworks from the conceptual level envisaged by the teacher. It seems difficult to make up for the gap, a difficulty so great that three barriers to learning interact amongst themselves:

- The difficulty of considering these two materials as different on a molecular scale;
- The difficulty of thinking that one same material (for example, liquid) can become crystal or glass by the cooling process;
- The difficulty of considering crystals as a class of objects with well-defined criteria.

The teacher's objective is therefore to remove these barriers to learning. The first barrier, based on the students' non-scientific level is the absence of questioning relative to crystals. It is reinforced by the idea that these objects are not part of an identifiable class by common characteristics (Vérin & Peterfalvi, 1985 and Westerback et al. 1985). We have stated the different persistent ideas on crystals and, unless these ideas are modified, the student will still continue to explain the presence of crystals in an artificial manner. One way to overcome this barrier could be to teach the student how to list the specific characteristics of crystals and those that distinguish them from other non-crystallised materials (glass; liquid; living beings). At an eighth-grade level these characteristics would be: "solid", "limited by the plane faces", "possessing planes of cleavage", "breaking while giving fragments of identical forms".

The difficulty of considering these two materials as different is reinforced by the fact that crystal and glass (hyaline quartz and windows, for example) can have the same appearance due to the verbal confusion between the two terms. In the expression glass in crystal, glass designates the object, and crystal designates the material. On the other hand, we have seen that by not distinguishing between the two concepts, the student is not able to explain the difference between breaking crystal (which generally gives identical geometric forms) and breaking glass (which results in irregular breaking). The teacher's objective regarding this barrier could therefore be to help the student become capable of explaining the difference between obtained forms. At this level, the conceptual level of the concept could be the following: "The form of crystals corresponds to a regular arrangement of particles of which it is composed (molecules in the eighth grade). The absence of form from the fragments of glass's characteristics corresponds to a disorderly arrangement of these particles". To be able to understand this, the student must know that material is formed from particles, that crystals are solids generally limited by plane faces, and often, contrary to glass, have planes of cleavage.

The difficulty of thinking that one same liquid can give either glass or crystal is reinforced by the idea that students regularly study these materials independently, one by one. They therefore don't get the chance to confront their origins. Also, this reinforces their ideas that they are different substances. During their schooling and everyday lives they have never had the opportunity to pay attention to this distinction. Overcoming this barrier supposes that the student has understood: that the structure of these two states of solid materials is linked to the precise organisation of the particles; and that we find the same particles in both liquids and solids, having observed examples of liquids, depending on the duration of the cooling process, giving the two types of structure. The visualised concept could be formed as following: **"**Crystals are a result of the slow cooling of a liquid that would result in glass if cooled rapidly".

A rock has no history

As before we once again come across a student's conceptual level that we could qualify as non-scientific: "rocks are a part of the landscape, just like rivers, trees, houses…" Students do not ask themselves questions about these inert objects that surround them. We can associate the following answers from students with this conceptual level:

- "We find rocks in fields";
- "A rock is a pebble, a stone, a boulder";
- "Mountains are made of rocks, and they are used for building houses and as a hiding place for animals".

This perceptive aspect that dominates is an aspect that does not provoke questions in the student's mind. It is *natural* and, so, "normal" for him to just see rocks around him (Happs, 1982; Dove, 1998, Ford, 2005).

Yet, what does the geology teacher want to accomplish? What the teacher wants to plant in the student's mind is the following idea: "Rocks have a structure and a precise layering that reflect the conditions in which the rock was formed". This conceptual level is then reviewed in the light of further rock studies (rocks from magmatic, sedimentary or metamorphic origin). If it is a rock from magmatic origin, we associate it with a cooling process separated into two sections of magma to the microlotic structure. If it's a rock from a sedimentary, crystallised origin, the precipitation and the deposit are from an over-saturated solution.

How do we advance from this non-scientific level, which often corresponds to the thought process of a student entering the eighth grade, to the conceptual level envisaged?

We have noticed two barriers to learning that are in opposition with this conceptual change, one of which has something in common with the previous study:

- The difficulty of considering rocks as a class of objects;
- The difficulty of considering rocks as the result of physical (change of state, deformation, precipitation) or chemical transformations, and the difficulty of considering the surface of the Earth, at an earlier period, as different from the one that we actually know.

The difficulty of considering rocks as a class of objects is reinforced by the current observations that echo the students' answers. Similar to findings by Happs (1982), Westerback et al. (1985), Blake (2005), also, many rocks are classed according to their construction material quality. On starting eighth-grade lessons, we notice that rocks are often considered on this bias. A way to overcome this stage would be to avoid focusing on the qualities or defects of the construction material, and instead offer an explanation of these properties from the structure of used rocks (Happs, 1982). Otherwise, we will remain on the side of the barrier that we thought had been overcome, meaning that the student has not progressed in relation to the idea that rocks are a "class of objects". At the eighth-grade level, the specific characteristics of the objects of this class could be the following:

- "Solids";
- "Non-living objects";
- "Constitute the Earth's underground";
- "Composed of various elements (grains, homogeneous mixture, fossils)";
- "Have a specific way of depositing (massif, layers…)".

The second barrier to learning is reinforced by the fact that rocks are solid, and it is therefore difficult to imagine them in another form (Dove, 1998; Kusnick, 2002; Ford, 2005) Furthermore, today we find them on the surface of the Earth, thus in thermodynamic conditions different from those within which they are formed. Moreover, the actual surface also creates phenomena that the students have not seen occur (Trend, 1998). Another reality that reinforces this complication is the fact that the transformations that they know happen over a short period of time, whereas rocks are the consequence of slow processes (Ault, 1982, Happs, 1982; Blake, 2005)

The Earth is a globe that contains an enormous reserve of magma

Similar to findings by Lillo (1994), Sharp et al. (1995), Marques and Thompson (1997) and Blake (2005), we have seen that this idea could be represented in two ways: magma occupies the entire interior of the Earth or magma occupies only the Earth's core. The conceptual level intended by the teacher is: "Magma is created in certain places within the mantle or the crust".

The difference between the two conceptual levels, i.e., that of the student and that of the teacher, is that, in the first case, magma already exists and the student does not therefore question the formation process, while, in the second case, the geologist demonstrates the relationship between the formation of the magma and certain phenomena connected to global tectonics (such as zone of divergence or of convergence of lithospheric plates, or hot points).

The History of Science has showed us that the idea of a solid Earth (with the exception of the external core), accepted by geologists, is very recent: it dates from this century. Even more symptomatic yet is the fact that geophysicists admitted it well before the geologists, as a result of the analysis of seismic wave propagation. Certain geophysicists, under the influence of Jeffreys, have even opposed Wegener's theory, as they considered that the Earth was more rigid than steel (Stanleys, 2005).

Three barriers to learning are evident:

The first barrier is outlined by the difficulty of coming out of a cycle of phenomena, which, as their name indicates, "circle" in the fashion of a computer program within which we would forget to insert an instruction allowing us to get out of the process. It's the research of the "correct form", as quoted by Astolfi and Peterfalvi (1993). In effect, similar to findings by Lillo (1994) and Marques and Thompson (1997) for these students, the centre of the Earth is assimilated by a fire (perhaps without a flame) that heats the core and liquefies its constituents. These constituents rise, turning into lava, or they heat the rest of the Earth's rocks, which melt, forming lava which itself rises to the surface. Everything is very coherent in this system.

The resistance to the conceptual change is reinforced by the idea of transmutation, a phenomenon well anchored in the student's mind, which enables the transformation of a substance composed of nickel and iron into other substances composed of silica, aluminium and other cations. Furthermore, it is reinforced by long-held knowledge (they know that worldwide there are many volcanoes that reject lava, which corresponds to a liquid interior) or facts that have recently been discovered (the analysis of seismic S waves indicate the presence of a liquid zone 2900 km deep). Finally, the movement of plates, the convection currants of the mantle, that assume, in their eyes, a substratum fluid, once again accentuating the idea of a liquid Earth, sometimes reinforced by what we read in certain textbooks (e.g., Tavernier, 2004; Périlleux & Thomas, 2005; Salviat & Desbeaux, 2005): "the plates float on the asthenosphere".

To overcome this barrier the students must acquire the idea that atoms cannot transform into other atoms. Is this possible in the eighth grade? Nothing is less sure as everything depends on the order within which teachers of physical science teach the chemistry syllabus. Nevertheless, it can be possible to construct an alternative model with the students, which does not refute the latter, and is also comfortable from an intellectual point of view. For example, it's the formation of magma from a solid material which composes the crust or the mantle. There will obviously be conflict for some time between these two explanations.

The second barrier to learning in the conceptual evolution is apparently the difficulty of differentiating between the long and short-term behaviour of materials (Trend, 1998). The primate of perception reinforces this barrier and is therefore in relation to the first barrier. It is also reinforced by the exclusive use of the coupled terms "solid/liquid". Obviously, these terms oppose the continents and the water of the oceans, lava and rocks, but are also often used to qualify the lithosphere and the asthenosphere, even though some differences exist. In school textbooks (e.g., Tavernier, 2004; Périlleux & Thomas, 2005; Salviat & Desbeaux, 2005), the lithosphere is often qualified as a solid in comparison to the asthenosphere which is considered to be either viscous or mostly solid with a very small proportion of liquid (1 to 2% according to the textbooks). This last term generally attracts students' attention as they find an explanation to the fluid's behaviour. Must we not therefore create a rupture in the way of envisaging the problem and of describing the lithosphere and the asthenosphere in terms of breaking/ductile behaviour? This latter could be considered as liquid behaviour on the geological time scale (Trend, 1998). The obtained conceptual level for opposing the two zones of the globe would be that: "the movement of the lithosphere is provoked by the deformation of the ductile asthenosphere". This change can be possible if the student is used to manipulating objects like wax, which can be deformed under the action of weak forces, but which will break under the action of strong forces applied in a short time frame. Another option is to study the deformation of materials under various temperature conditions because it can show the necessity of changing the criteria for qualifying solid materials.

A third barrier to learning is that, in the student's minds, only the heating process is capable of transforming the mantle or the crust into liquid (Lillo, 1994; Marques & Thompson, 1997). It is the model of everyday life: the idea is reinforced by the fact that the heating process produces practically all fusions. On the other hand, it does not allow the understanding of liquefaction or vaporisation at a constant temperature, for example, changing the state of butane from a liquid to a gas. The change in thinking that needs to be introduced is that: "fusion can be produced by heating and/or by decompression".

We are well aware of the fact that eighth-grade students still do not have the precise relative knowledge of the concept of pressure because they will not study it until the ninth grade. The representation that they have of this concept is generally the following: "It is an action (sometimes a substance in movement), which packs the material down (which does not indicate whether the student thinks of molecules or atoms)". It is also how some of them explain the liquid state of butane in a lighter or a bottle. By enriching the spectrum of the conditions within which a change of state can be produced, we can bring the students to reconsider their initial explanation of fusion. They will then see that fusion is possible without a variation of temperature but with a reduction of pressure. The example of the lighter within which we observe butane in a liquid state become gas when we open the valve is an example of a possible demonstration. This conceptual level permits the explanation of the change of state that is produced in the asthenosphere on a level of divergence zones.

IMPLICATIONS: POSSIBLE DEVELOPMENT LEVELS OF ANALYZED STUDENTS' ALTERNATIVE FRAMEWORKS IN THE EIGHTH-GRADE

The knowledge that has been gradually acquired by the scientific community during the development of science, shall be referred to herein as "Reference Knowledge" (Giordan & DeVecchi, 1987). Analysing the Reference Knowledge in order to construct a teaching sequence can be done not only by using university textbooks, but also by putting these books, as well as Official Instruction texts, in relation to the students' alternative frameworks and the barriers to learning that they bring about. This is what De Vecchi (1994) clarifies: "To our knowledge, the conceptual levels should be constructed from a precise analysis of the concept (Reference Knowledge), of the use of which it has made for itself, and the barriers to learning that the students come head-to-head with in building their own knowledge". In one year, the level of understanding of a concept such as that of "crystal", "rock" or "volcano", "Earth", is enriched in the light of the barriers to learning overcome.

Figure 4 proposes a concept map showing the different levels of development of a same concept in the eighth grade. These different conceptual developments were arranged in the context of which the edges are rectilinear. The students' alternative conceptions given are in a box with a bold background. The arrows carry out the conceptual change from one level to another. An arrow generally crosses a framework-conception, thus showing that this conception must be overcome. The concept map as a whole forms a network as often many concepts or sub-concepts intervene in the construction of the envisaged concepts. It is the case, for example, concerning the concept of the rock which supposes only at a moment that the students have constructed the concept of crystal. These different conceptual developments have been written under an operative form that permits the explanation of geological phenomena considered in class.

If we take the case of the rock concept, we find the different attributes that we previously quoted. They could be broached together, or separately, depending on the established progress. One of the proposed conceptual levels could be that "the rock is an underground constituent" (level 1). The superior level would be that "a rock is constituted of grains" (level 2). It is no longer the hardness or the coherence that matters, it is the fact that it is composed of distinctive elements. The fact that "the rock has a history" could be the following objective.

These proposed conceptual levels are the result of class activities in the context of different lessons and are therefore operative. The rock concept is not studied under the form of a monograph, but constitutes one of the conducting threads of the geology sequences. The overlapping of one level onto another does not always make progress. It can be done by integrating new knowledge. We therefore advance from the level wherein "the rock is constituted of grains" (joined together or not) to the level wherein "the rock is composed of crystals and/or glass". This is done after having constructed the crystal concept, which always corresponds to the second level previously defined.

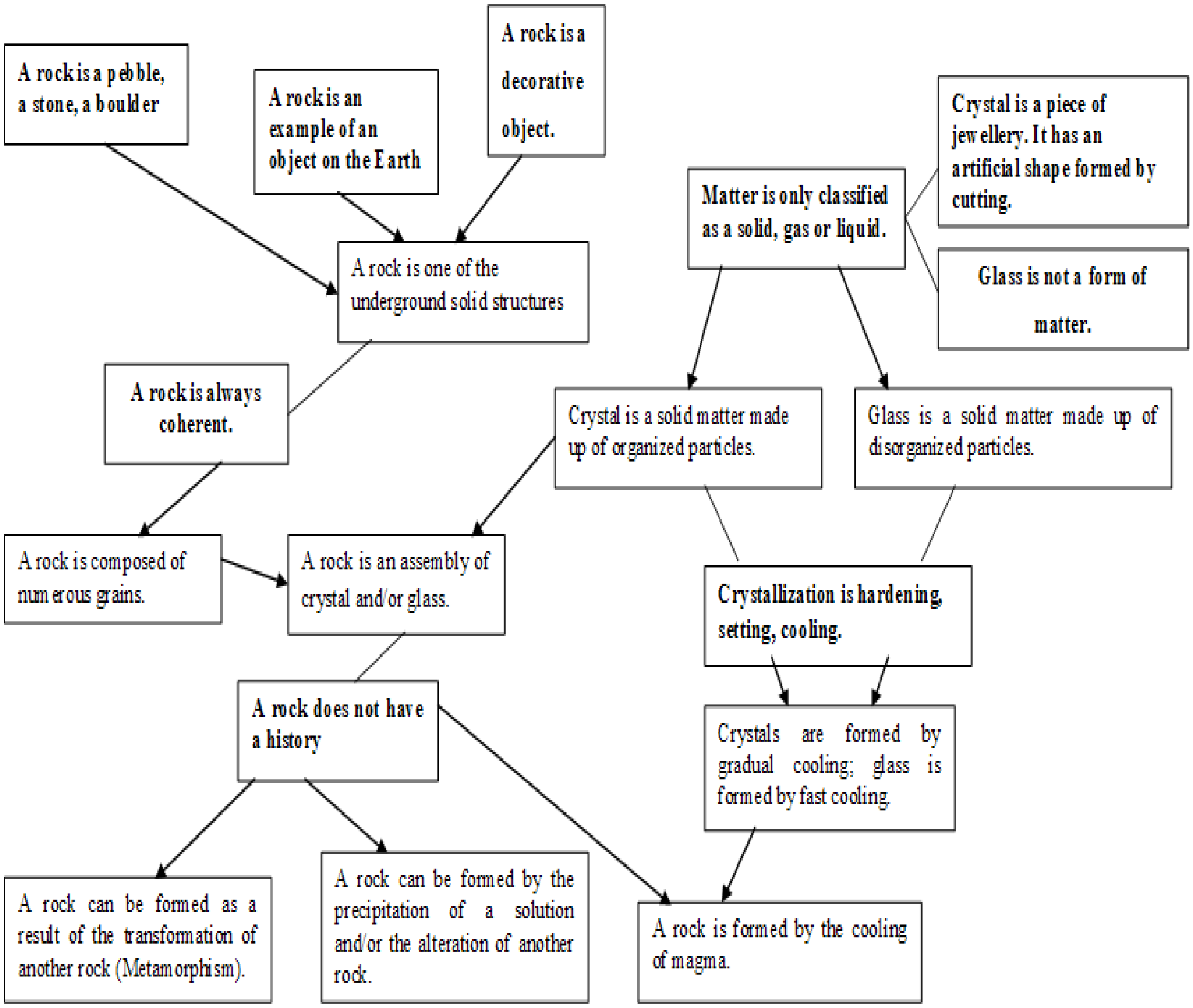

Figure 4. The different conceptual levels: Rock – Crystal – Glass - Students' alternative frameworks defined in bold.

On the other hand, these conceptual developments have been put into the perspective of the students' alternative frameworks. The change of level is done by the modification of initial knowledge, such as:

To go from the idea that "a rock is a gathering of crystals" to the idea that "a rock is the result of the cooling process of magma" presupposes that the student has overcome the learning barrier constituted by "a rock (inert material) has no history". Students can progress from the idea that "a crystal and a glass are two identical solids" to the idea that "a crystal is composed of ordered particles" (even though a glass is composed of particles dispersed without an precise order), if they have overcome the stage of categorical thinking that leads them to consider that all the substances that belong to the class of solids have the same structure.

Accordingly, scientific knowledge is developed in relation to what the student thinks or does not think in the absolute. These conclusions are supported by Schnotz et al. (1999) in the quotation: "a concept is a denomination and a definition, otherwise said as a name laden full of sense, capable of fulfilling a discriminate function in the interpretation of certain observations". This signifies that it does not only consist of an accompanied word in its definition.

CONCLUSION

The results show that children's alternative frameworks vary in terms of their differentiation; organisation and vocabulary, suggestive of different levels of understanding that facilitate their categorisation as alternative frameworks.

In addition, this study highlights the possibility that within a conceptually-confined area like geosciences, students' understanding of closely related concept groups tends to be uneven, creating a "critical barrier" (Ault, 1984), preventing the long term development of a Scientific, holistic understanding of how the Earth functions as a dynamic, integrated system. As pointed out above, this necessitates a Scientific, descriptive understanding of each concept group as well as a casual understanding of the relationship between them.

This study revealed the alternative frameworks of the students in relation to the following three main types of barriers to learning emphasised by these all students' productions are grouped.

- Crystals do not correspond to a precise organisation of the material;
- A rock does not have a history;
- The Earth has a liquid interior.

In considering the function of alternative frameworks on children's understandings of earth science concepts, it may be that they operate in a analogous way to the possible sub-conscious intuitive theories of naïve physics held by children, with structure their knowledge acquisition of physical phenomena (Vosniadou & Brewer, 1992, Vosniadou, 1994). Although such comparisons cannot be taken too far and would merit further investigation, it is suggested that children's existing alternative frameworks may influence the way knowledge is interpreted and understood in this domain, particularly evident when the appropriate alternative framework is absent.

The results from this study can be used to inform Earth science instruction in this area and at this grade level. It is suggested that in order to avoid these grouped critical barriers and develop a deep understanding of geology, a concept map showing the different levels of development of a same concept in the eighth grade are proposed.

Identifying critical barriers to learning linked to alternative frameworks, and preparing the concept maps not only help to develop teaching strategies, but also provide a first step for future research, which should address the effects of developing guide materials and teaching strategies, as well as organizing workshops for teacher training.

REFERENCES

Abraham, M.R., Williamson, V.M. & Westbrook, S.L. (1994). A cross-age study of the understanding five concepts. *Journal of Research in Science Teaching*, 31, 147-165

Astolfi, J.P. (1985). Procédures d'apprentissage en sciences expérimentales. Paris: INRP.

Astolfi, J.P. & Peterfalvi, B. (1993). Obstacles et construction de situations didactiques en sciences expérimentales. *Aster*, 16, 103-141.

Ault, C.R.Jr. (1982). Time in geological explanation as perceived by elementary school students. *Journal of Geological Education*, 30, 304-309.

Ault, C.R.Jr. (1984). Everyday perspective and exceedingly unobvious meaning. *Journal of Geological Education*, 32, 89-91.

Bezzi, A. & Happs J.C. (1994). Belief systems as barriers to learning in geological education. *Journal of Geological Educatio*n, 42, 134-140.

Blake, A. (2005). Do you children's ideas about the Earth's structure and processes reveal underlying patterns of descriptive and causal understanding in earth science. *Research in Science Technological Education*, 23(1), 59-74.

B.O.E.N. (2005). Programmes des 4ème des collèges.

De Vecchi, G. (1994). Elaborer des niveaux de formulation en prenant en compte les conceptions des apprenants. In A. Giordan, Y. Girault & P. Clement (Ed.), Conceptions et connaissances (pp. 46-82). Berne : Peter Lang.

Dove, J.E. (1998). Students' alternative conceptions in Earth science : A review of research and implications for teaching and learning. *Research Papers in Education*, 13, 183-201.

Driver, R. & Bell, B. (1986). Students' thinking and the learning of science: a constructivist view. *School Science Review,* 67, 443-455.

Driver, R., Guesne, E. & Tiberghien, A. (Eds) (1985). *Children's Ideas in Science*. Buckingham: Open University Press.

Duff, D. (1993). *Holmes' Principles of Physical Geology* (4nd ed.). London: Chapman and Hall.

Ford, D.J. (2005). The challenges of observing geologically: third graders' descriptions of rock and mineral properties. *Science Education*, 89, 276-295.

Gilbert, J.K & Watts, D.M. (1983). Concepts, misconceptions and alternative conceptions: changing perspectives in science education. *Studies in Science Education*, 10, 61-98.

Giordan, A. & DeVecchi, G. (1987). Les origines du savoir. Paris : Delachaux &Niestlé.

Gohau. G. (1987). Histoire de la géologie. Paris : La découverte.

Happs, J.C. (1982). *Some aspects of student understanding of rocks and minerals*. Science Education Research Unit Working Paper. No: 204. New Zealand: Waikato University.

Happs, J.C. (1985). Regression on learning outcomes: some examples from the Earth Sciences. European Journal of Science Education, 7(4), 431-443.

Haynes, D., Symington, D. & Martin, M. (1994). Drawing science activitiy in the primary school. *International Journal of Science Education*, 16(3), 265-277.

Hume, J.D. (1978). An understanding of geologic time. *Journal of Geological Education*, 2, 141-143.

Kusnick, J. (2002). Growing pebbles and conceptual prisms-understanding the source of student misconceptions about rock formation. *Journal of Geoscience Education*, 50(1), 31-39.

Lillo, J. (1994). An analysis of the annotated drawings of the internal structure of the Earth made by students aged 10-15 from primary and secondary schools in Spain. *Teaching Earth Sciences*, 19(3), 83-87.

Marques, L. & Thomson, D. (1997). Portuguese students' understanding at ages 10-11 and14-15 of the origin and nature of the Earth and the development of life. *Research in Science Technological Education*, 15(1), 29-51.

Newton, D.P. & Newton, l.D. (1992). Young children's perception of science and the scientist. *International Journal of Science Education*, 14(3), 331-348.

Osborne, R. & Freyberg, P. (Eds) (1985). *Learning in Science: The Implications of Children's Science*. London:Heinemann.

Osborne, R. & Wittrock, M. (1985). The generative learning model and its implications for science education. *Studies in Science education,* 12, 59-87.

Périlleux, E. & Thomas, P. (2005). Biologie Géologie – 4. Paris: Nathan.

Russell, T., Bell, D., Longden, K. & McGigan, L. (1993). Primary SPACE Research Report: *Rocks, Soil and Weather*. Liverpool: Liverpool University Press.

Salviat, N. & Desbeaux, B. (2005). *Sciences et techniques* biologiques et géologiques – 4. Paris : Magnard.

Schnotz, W., Vosniadou, S. & Carretero, M. (Eds). (1999). *New perspectives on conceptual change*. London: Pergamon.

Sharp, J.G., Mackintosh, M.A.P. & Seedhouse, P. (1995). Some comments on children's ideas about Earth Structure, volcanoes, earthquakes and plates. *Teaching Earth Sciences*, 20(1), 28-30.

Stanleys, S.M. (2005). *Earth System History* (2nd ed). New York: W.H.Freeman & Co.

Stavy, R. (1988). Childrens' Conception of Gas. *International Journal of Science Education*, 10, 553-560.

Tavernier, R. (2004). *Sciences et Technologies* – CM. Paris : Bordas

Tazieff, H. & Willemin, P. (1994). Le feu de la Terre (Paris : FR2 / Gaumont Télévision/Ciné documents Tazieff. (série documentaire en 6 volets de 55 : Du volcan interdit à la montagne de Dieu, Etna : sur les traces d'Empédocle, Le triangle de l'Afar, La cordillère des volcans, Java, Les cratères fertiles)).

Trend, R. (1998). An investigation into understanding of geological time among 10-and 11 years old children. *International Journal of Science Education*, 20(8), 973-988.

Vérin, A. & Peterfalvi, B. (1985). Un instrument d'analyse des modèles implicates de l'enseignement scientifiques chez les enseignants. Aster, 1, 7-28.

Vosniadou, S. & Brewer, W.F. (1992). Mental models of the Earth: a study of conceptual change in childhood. *Cognitive Psychology*, 24, 535-585.

Vosniadou, S. (1994). Capturing and modelling the process of conceptual change. *Learning and Instruction*, 4, 45-69.

Westerback, M. E., & Azer, N. (1991). Realistic expectations for rock identification. *Journal of Geological Education*, 39, 325– 330.

Westerback, M.E., Gonzalez, C. & Primavera, L.H. (1985). Comparison of preservice elementary teachers anxiety about teaching students to identify minerals and rocks and students in geology courses anxiety about identification of minerals and rocks. *Journal of Research in Science Teaching,* 22, 63-79.

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Appendix A

The Q-Sort test was presented in the following manner:
Dear student,

In the first three questions you are asked to associate, by classifying, a key concept (in bold) to ten words of everyday vocabulary (classed by alphabetic order in each list). To do this, you transfer, on the answer sheet, the number of words in the boxes that correspond to the question. At the top, you will indicate the word which, in your opinion, is closest to the key concept and, at the bottom, those with the least association. The boxes in the middle correspond to words that are neither close nor far from the key concept.

1. Crystal: 1.atom; 2.glass; 3.ice; 4.jewellery; 5.liquid; 6.order; 7.regular; 8.rock; 9.solid; 10.shiny

2. Earth: 1.continent; 2.core; 3.crust; 4.heat; 5.liquid; 6.magma; 7.mantle; 8.ocean; 9.rock; 10.solid

3. Volcano: 1.continent; 2.explosion; 3.fire; 4.fracture; 5.gas; 6.heat; 7.lake; 8.lava; 9.magma; 10.pressure

Appendix B

The Survey Questions:

The First section

The students were asked the following questions:

Dear Student,

The video document has shown a few eruptions of a volcano, Mount Etna.

1. Draw a volcano as you imagine it and replace the products that are rejected.
2. On the drawing, show precisely where the products (gas, lavas, and different-sized rocks) could come from.
3. Pieces of rocks coming from volcanoes (solidified lavas, solid projections) are arranged on your table. Using the information brought to you by the film, explain how these different rocks could be formed.
4. After a certain amount of time (a few weeks or a few months) the eruption stops. For which reasons?
5. Mount Etna erupts on a regular basis. What makes the lava rise and expel the rocks?

The second section

The students were asked the following questions:

Dear Student,

1. Calcite and aragonite are both composed of carbon and calcium molecules (a combination of carbon, oxygen and calcium atoms). Nevertheless, these crystals do not have the same form (a calcite crystal, a rhombohedra crystal and an aragonite crystal were drawn). Draw what you would observe if you looked at a calcite crystal and an aragonite crystal with a microscope that enlarges them a million times.

2. Please explain, what is a crystal?

The third section

The students were asked the following questions:

Dear Student,

1. Please explain the global spread of volcanoes on the surface of the Earth and in doing this, represent the latter in cross-sections.

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Seventh-grade Students' Understanding of Chemical Reactions: Reflections from an Action Research Interview Study

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This paper discusses seventh-grade students' explanations of dissolution and combustion and also identifies their understanding of the differences between physical and chemical changes. A teaching strategy was initially negotiated within an action research group and this strategy was then employed in teaching seventh-grade students. The teaching approach applied the idea that discrete particle changes can be used to differentiate chemical reactions from simple physical changes. Data were collected by an action research group teacher who conducted interviews with dyads of students from different chemistry classrooms. The interviews were transcribed, subsequently analyzed and evaluated in co-operation with researchers from the university. The main mistakes and alternative conceptions that have been identified are discussed. Further, some implications for developing appropriate teaching strategies and curriculum materials are also summarized.

Keywords: Chemical Reactions, Students' Conceptions, Action Research

INTRODUCTION

Explaining macroscopic phenomena on the particulate level is considered an essential idea of modern science and science teaching (Johnstone, 1991). Nevertheless, science education research (Novick & Nussbaum, 1978; Pfundt, 1982) indicates that this is not an easy task to achieve. A large variety of conceptual gaps in students' understanding of the particulate level (Andersson, 1990; Garnett, Garnett & Hackling, 1995) or related issues, such as the concept of matter (Krnel, Watson & Glazar, 1998), have been also identified.

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In science classrooms in Germany, learning about the particulate nature of matter typically begins in early secondary chemistry education. The first teaching approach towards the particulate level in most of Germany's 16 States takes place in 6th or 7th grade chemistry (age range 11-13), although each of the States uses a different syllabus.

Six years ago, a group of researchers and practitioners started a project of Participatory Action Research in chemical education (Eilks & Ralle, 2002; Eilks, 2002). The project aims at developing 'New ways towards the particle concept' (Eilks & Moellering, 2001). The central objective of the project is the design and

Table 1. Distinction between chemical and physical changes

Level of Change	Physical Change	Chemical Change
Macroscopic	Changes in the form a specific kind of matter appears in or its localisation related to other substances	Changes of specific kind(s) of matter into different kinds of matter
Sub-microscopic (particulate)	Change in the arrangement of discrete particles of a specific kind of matter or in their localisation related to discrete particles of other substances	Changes in the discrete particles of a substance or substances into discrete particles of a different substance or substances
Examples	Changes in the state of matter, dissolution, diffusion	Chemical reactions

development of innovative and effective teaching strategies dealing with the particulate nature of matter in lower secondary chemistry teaching. This approach targets the development of lesson plans, the application of cooperative learning strategies, and the integration of new media into teaching and learning.

The development, testing, and revision of teaching strategies follow the pattern of Participatory Action Research and are accompanied by diverse approaches in evaluating their effectiveness (Eilks & Ralle, 2002; Eilks 2002). The evaluation focuses on students' achievement and understanding, including the acceptance and feasibility of the specific teaching strategies, from both the students' and the teachers' perspectives (e.g. Eilks, 2005). This evaluation is partly conducted by teachers from the action research group in small scale action research studies. This approach promises to contribute towards 1) optimizing teachers' practices and 2) fostering teachers' competencies in evaluating their students' learning and understanding, thereby contributing to their professional development. Similar projects in the past exemplified the potential of different forms of action research in evaluating students' understanding, initiating change, and improving teachers' professional skills (Scott & Driver, 1998; Valanides, Nicolaidou & Eilks, 2003; Gilbert & Newberry, 2004).

In this paper, an interview study focusing the evaluation of students' ability to differentiate between physical and chemical changes is described. The distinction between physical and chemical changes in matter follows the interpretation discussed by Hesse and Anderson (1992) or Eilks, Leerhoff, and Moellering (2002). From this perspective, physical changes are changes (i) in the appearance of matter on the macroscopic level and (ii) a rearrangement of particles on the sub-microscopic (particulate) level, whereas chemical changes constitute (i) changes in matter itself on the macroscopic level and (ii) changes in discrete particles on the particulate level, as indicated in Table 1.

RELATED RESEARCH

During the last twenty-five years, research has extensively investigated students' understanding and alternative conceptions in science, including their underlying implications for the teaching and learning of science. Various review studies tried to present an integrated picture of findings related to characterising matter and its properties.

One of the first concepts introduced in early chemistry teaching is usually the idea of matter[1] and its properties. The concept of matter is of central importance to the particulate nature of matter and related issues (Andersson, 1990; Garnett et al., 1995; Krnel et al., 1998). Krnel et al. (1998) reviewed related research and outlined aspects of students' insufficient understanding of the concept of matter and its properties, prior to introducing chemical changes. For example, in students' thinking there is no clear distinction between matter and other things not belonging to the category, such as forms of energy or feelings. Other categories, like mass or expansion, which facilitate the distinction between matter and forms of energy, are not always available or are not correctly applied (Stavy, 1990).

Similar misunderstandings also arise from an insufficiently developed 'chemical' understanding when dealing with the concept of properties. Sometimes, students cannot distinguish clearly between the use of relevant properties describing matter and those relating to the form or size of objects. For example, students use temperature (an intensive property) or volume (an extensive property) to characterise matter itself (Krnel et al., 1998; Solomonidou & Stavridou, 2000).

Mistakes and communication problems between teachers and learners also arise from semantic problems in the use of names and notions (Krnel et al., 1998; Johnson, 2000). Names and notions are usually used in their everyday or trivial way. In most cases, such usages are not identical to the scientific meaning of the word or term. For example, the German word 'Stoff' has different meanings, such as cloth, stuff, subject matter, and in chemistry: matter or substance.

[1] The term matter here is used as translation of the German term 'Stoff'. Other terms, such as 'Material' or 'Substanz' are sometimes used. Distinctions between matter and substance from English cannot be easily transferred to German language use.

Several other problems have been also identified in characterising the properties of matter and chemical change which are caused by misinterpretations of the relationship between matter and its particles. The properties of a substance are sometimes considered as identical to the properties of the particles themselves, without taking into consideration the important differences between the macroscopic and the particulate level (Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993; Johnson, 1998).

Chemical and Physical Changes

Chemical reactions in most cases are initially introduced on a phenomenological level. Several researchers (Pfundt, 1982; Meheut, Saltiel, & Tiberghien, 1985; Johnson, 2000) stated that students do not often consider chemical reactions as a complete transformation of the matter itself, but only as a change in its appearance or as a change in the state of matter. Consequently, students tend to make no clear distinctions between physical and chemical changes (BouJaoude, 1991). Chemical reactions are often considered as a process of 'mixing' the initial substances, because the relationship between the macroscopic world and the particulate level of matter is not clearly understood (Johnstone, 1991; Johnson, 2002). Thus, the products of chemical reactions are often considered as mixtures of the initial substances, and their properties as a combination of the properties of the initial substances (Meheut et al., 1985; Ebenezer & Erickson, 1996).

Students usually believe changes on the particulate level occur in the same fashion as those on the macroscopic level (Lee et al. 1993, Andersson, 1990). Chemical reactions are sometimes introduced as a rearrangement of atoms without making it clear that this automatically implies changes in the discrete particles, and their constituents (atoms) as well. This gap in understanding usually relates to the Dalton understanding of chemical change which is quite often used in German textbooks. However, a correct understanding of chemical models is not always presented to the students simultaneously by their textbooks (Eilks et al., 2002). If students conceptualize the rearrangement of atoms, but do not associate any further changes connected with the atoms or the sub-atomic particles that constitute them, the danger exists that the students may view that the new substance is 'just' a mixture of the initial substances.

Reflection upon the nature of models and their strengths and limitations may help students to understand the differences between Dalton's model and their experiences from the macroscopic world when mixing things. Unfortunately, students are not always aware of the correct use of models. They often neglect either the fact that different ideas and concepts have to be applied within models or that models are not an exact replication of reality (Grosslight, Jay, Unger, & Smith, 1991; Lee et al., 1993; Taber, 2001).

Several researchers (Ahtee & Varjola, 1998; Johnson, 2002) suggested that misunderstandings may be reduced by developing a clear understanding on the particulate level in the early stages of schooling. This, however, can only happen if the particulate interpretation of chemical changes is introduced quite early, if this concept is comprehensible and if a clear distinction between the macroscopic and the microscopic levels is constructed (Johnson, 2002). Delayed introduction of the particulate nature of matter may consolidate students' naïve conceptions about physical and chemical changes, thus the particulate explanation may not become an equally-valued basis for students' interpretation of phenomena. In such a case, students will still attempt to explain most phenomena on the macroscopic level without considering the particle level (Stavridou & Solomonidou, 1998).

However, if a particle concept is introduced quite early in science teaching, we have to carefully investigate which explanation for chemical reactions on the particle level should be used. In most cases, the first particle model to be introduced in chemistry teaching is a model of discrete particles. Hesse and Anderson (1992) outlined that an understanding of chemical reactions must be introduced as a change in the constituent discrete particles of the initial substances (Andersson, 1986; Gomez, Pozo & Sanz, 1995). This strategy promises to foster better understanding of the distinctions between chemical reactions and physical changes. Taber (2001) also argues that it would be more productive to start thinking in terms of discrete particles in chemistry education rather than on the level of atoms, provided, of course, that changes in the discrete particles are not neglected. The distinction between these two levels is presented in table 2.

Usually in German chemistry classrooms, different models are progressively introduced. Introductory chemistry teaching starts with a model of particles. Later, in most cases, a simple model of atoms is introduced following the historical ideas of Dalton, and chemical reactions are explained as a rearrangement of atoms. In most cases, the concepts of atomic structure and bonding are introduced much later during grade nine.

Unfortunately, no clear distinction is made in some textbooks between atoms and the discrete particles of a substance (Eilks et al., 2002). Even when the concept of atoms is accompanied by a distinction between atoms and discrete particles, the distinction is not clearly understood among younger students. Both models use spheres to represent particles. A mixture of different

Table 2. Levels of understanding from macro- to submicroscopic

Macroscopic level (The phenomenological world)	The 'out-of-reach world'	Things outside the earth that can be seen and measured (e. g. objects in astronomy, although they cannot be reached).
	The macroscopic world	Tangible things from the macroscopic world around us that can be seen and characterized with our eyes, ears, etc.
	The microscopic world	Things from the macroscopic world that are too small to be seen, but which can still be characterized using microscopes and other measuring tools.
Sub-microscopic level (The 'world' of the particulate nature of matter)	The level of discrete particles	The level of particles and structures which are discrete, e. g. molecules, atoms in inert gases, or structures in solid bodies
	The level of atoms	The level of atoms building up discrete particles and structures
	The level of atomic structure	The level of sub-atomic building units (electrons, neutrons, protons) responsible for bonding and structure

models often constitutes a source of confusion (Carr, 1984). The application of a model of atoms without relating them to the level of discrete particles usually leads to an understanding of chemical reactions as mixtures of the initial substances (Ben-Zvi, Eylon & Silberstein, 1987; Garnett et al., 1995; Ebenezer & Erickson, 1996).

Understanding combustion in early chemistry teaching

Oxidation and combustion in early chemistry lessons constitute an area where similar problems have been investigated and described. These problems occur frequently, especially when oxidation and combustion are closely connected to everyday life experiences. Personal experience usually constitutes a main source of alternative explanations and conceptions among pupils (Pfundt, 1982). Naïve interpretations of everyday phenomena usually give rise to alternative conceptions where students believe that all chemical reactions are irreversible, that combustion is usually associated with destruction or disappearance of matter and its mass, or that combustion always produces gaseous compounds (BouJaoude, 1991; Nakhleh, 1992).

One possible explanation stems from younger pupils' belief that 1) matter, 2) mass as a necessary attribute of this matter and 3) the principle of conservation of mass are not interconnected. Thus, some students may think that matter exists without having any mass and, consequently, that chemical changes result in the loss of mass or in the creation of something from nothing (Stavy, 1990). Gomez et al. (1995) stated that the principle of the conservation of mass is more frequently accepted for physical changes rather than for chemical reactions. These problems are not restricted to early chemistry learning, but they often occur among older students who have been taught chemistry for many years (Valanides et al., 2003).

Understanding dissolution in early chemistry teaching

Physical processes themselves are often not correctly understood, and several research studies investigated students' understanding of the states of matter (Andersson, 1990) and the processes of dissolution and distillation (Johnson, 1998; Valanides, 2000a, 2000b). For example, dissolution is often viewed as a loss of substance or mass, because it is considered to be a process resembling evaporation (Johnston & Scott, 1991; Lee et al., 1993; Krnel et al., 1998). Dissolution is also related to misconceptions at the particle level, because students believe either that similar changes also occur at the particle level (Valanides, 2000a, 2000b) or that the sub-microscopic particles become lighter (Johnston & Scott, 1991). Similar conceptions are also connected to changes in the state of matter (Valanides, 2000b). These ideas occur especially frequently if the process of dissolution is not clearly separated from the process of changes in the state of matter. Thus, dissolution is sometimes considered as melting of the dissolved substance (Lee et al., 1993; Ebenezer & Erickson, 1996; Valanides 2000a).

Seventh-grade Students' Understanding of Chemical Reactions

Initial Issues Related to a Revised Teaching Strategy

Practicing teachers repeatedly reported that they faced problems when teaching the particulate nature of matter, and research confirmed the persistence of these problems. In Germany, various historical models are generally used as guidelines for teaching the particulate nature of matter. But these models are often not discussed with sufficient care. Students are not usually motivated during the lessons or may face difficulties in correctly conceptualizing the use of the respective models (Andersson, 1986). Analysis of German textbooks also indicated (Eilks, et al., 2002) that even common teaching concepts represented in textbooks are sometimes not consistently or clearly differentiated from the perspective of using different models. Unfortunately, some of the inconsistencies in chemistry textbooks resemble those reported in the literature concerning students' inattentiveness in model use (Eilks, et al., 2002). Some textbooks seem to perpetuate common misconceptions that are spread among the students and create even more confusion in them (Eilks & Moellering, 2001; Eilks, 2003a).

Thus, a project of Participatory Action Research (Eilks & Ralle, 2002; Eilks, 2002) in chemistry education was initiated about seven years ago. The project developed and investigated the effectiveness of different teaching approaches concerning the particle concept. The project followed a cyclical, step-by-step development of teaching strategies and materials that should be compatible with students' understanding and learning capabilities. It also invested in recent teaching methods, e.g., use of new media or cooperative learning.

The action research group decided to develop a new model approach for the particle concept which is consistent in and of itself. The group would follow the new model through the different stages of chemistry education in hopes avoiding breaks in students' learning caused by rapid switching from one chemistry model to another. The new model should not only be internally coherent, but also scientifically acceptable and compatible with students' learning capabilities as well. Similar ideas had been proposed by de Vos and Verdonk (1995). But their concept was only worked out for the first step. The objective was to design and develop a coherent and well-tuned didactical sequence and specific guidelines for effectively teaching the particulate nature of matter in lower secondary science. Their main guiding principle was to coordinate the systematic development of students' knowledge over different stages of their education without discrepancies from the basic model that would be initially introduced. Thus, the objective was to avoid difficulties arising from the progressive adoption of new models that played a role in the history of science. The progressive introduction of new models, following their historical development necessarily, demands relevant 'conceptual changes' in students' knowledge rather than a simple enrichment in their existing knowledge structures.

For example, if a model is introduced where spheres represent discrete particles (such as molecules, ions (both mono- and multi-atomic), or atoms in inert gases and metals), then students at a later stage often face lasting difficulties in distinguishing among these particles and their constituent entities (the single atoms that are also usually represented by spheres in different models). Teachers are usually, but not always, able to make a clear distinction between discrete particles and atoms, however their students often are not able to do so and therefore face many difficulties. This situation does not encourage pupils' motivation to be cognitively engaged in learning chemistry.

This approach has implications for students' understanding of chemical reactions. Chemical reactions are introduced in some German curricula as a rearrangement of particles. For some of these concepts, even textbooks do not introduce a clear distinction between the level of simple (discrete) particles and the level of atoms, as discussed in table 2 (Eilks et al., 2002). Therefore, students attempt to rearrange simple discrete particles to explain chemical reactions. Consequently, they may conceptualize chemical reactions as a kind of dissolution or diffusion (or just mixing) which, however, are physical processes and not chemical changes.

The application of the sphere-model for discrete particles does not facilitate the explanation of changes in substances during chemical reactions, as shown in figure 1. The model does not allow the composition of a pure substance as the product of a reaction of two initial substances, because such a product has to be built up by identical spheres representing the particles of the product. The formation of these spheres is not possible within the model. Additionally, the reaction from one initial substance into two or more products is not possible (in figure 1 the reverse reaction). In this case, we should have one kind of identical spheres at the beginning, and two or more kinds of particles after the completion of the reaction. This cannot be explained by any kind of 'rearrangement'.

The participants in this action research group strongly believe that there is no need to introduce a 'model of discrete particles to be represented by spheres' as suggested by most German textbooks. The group preferred the introduction of a 'model consisting of discrete particles of different form and size'. The group agreed that this approach will:

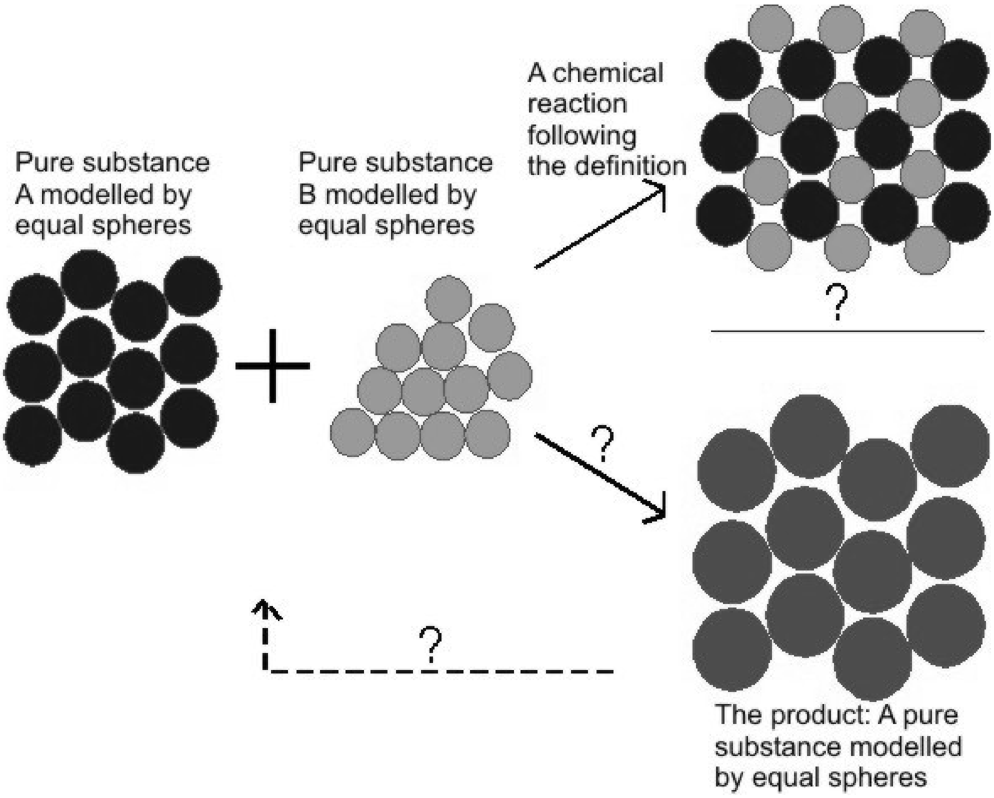

Figure 1. Problems in explaining chemical reactions based on a simple model of spheres representing discrete particles

- Allow an understanding of chemical reactions as a change from the constituting particles of specific kind(s) of matter into the constituting particles of different kinds of matter. A chemical reaction on the level of simple particles should be connected to the idea that these particles undergo changes leading to the formation of totally different particles of the new substance or substances (e.g., Hesse & Anderson, 1992).
- Reduce the possibility of the occurrence of misunderstandings concerning the distinction between the levels of discrete particles themselves and of their constituting entities, i.e., the level of atoms.
- Be helpful in facilitating the later introduction of different types of discrete particles represented by this model (molecules, ions, or atoms of inert gases).
- Allow dealing with the same model across the whole chemistry curriculum and facilitate a consistent continuation to the level of atoms and sub-atomic particles as the building units of the discrete particles that will be initially introduced. Thus, only one model will be introduced that will be developed step by step while looking more and more deeply into the sub-microscopic structures.

For the purpose of the present study, some of the essential units of chemistry teaching at the first year in Germany seem to be relevant. The course regularly consists of units related to matter and its properties, states of matter, dissolution, methods of separating matter, (e.g., filtration, distillation, or extraction) and initial understanding of the concept of chemical reactions. The concept of chemical reactions is introduced primarily using examples of combustion and oxidation.

The teachers structured all the units using experiments and applications from everyday life, and an attempt is made to connect macroscopic explanations with the sub-microscopic level. Using this approach, experiments are usually conducted by students themselves as hands-on activities, which is commonly accepted as a main goal of chemistry teaching in Germany. Nevertheless, teaching is commonly built around teacher-centered, didactic instruction (informally called "chalk and talk" methodology by many English-speaking teachers) with low levels of direct student participation and pupil-centered activity (Fischer, Klemm, Leutner, Sumfleth, Tiemann, & Wirth, 2005).

In the negotiated teaching strategy, explanations on the sub-microscopic level are based on a simple concept of discrete particles, as suggested by Taber (2001). Emphasis is placed on more frequently explaining school chemistry from the level of discrete particles than from the level of atoms. All explanations on the sub-microscopic level are worked out using multimedia-based learning environments (Eilks & Moellering, 2001).

These multimedia-based environments offer different learning sequences, including video clips of experiments that were previously conducted in the classroom, theoretical explanations, and animated illustrations at the particle level. Chemical reactions are introduced as changes of discrete particles (e.g., Hesse & Anderson, 1992), and these changes are later explained as a re-arrangement of the building blocks of these particles, e.g. atoms and their constituent sub-atomic particles, into new discrete particles forming the new substance or substances. This second step had not been discussed in detail in most of the learning groups prior to this study. In those few groups where such a discussion took place, only the initial idea that these discrete particles are built up from single atoms was introduced.

BACKGROUND AND METHOD

The process of developing teaching materials and strategies via Participatory Action Research is accompanied by several different kinds of evaluation. Some aspects are evaluated in broader case studies by the participating researcher(s) (e. g. Eilks 2005), while other aspects are evaluated through smaller-scale case studies conducted by the participating teachers (e. g. Witteck & Eilks, 2006). The main purpose of these studies is to gain insights into possible ways for further improvement in a new cycle of development. This also more thoroughly involves the participating teachers in the assessment processes within the action research network, and familiarizes them with the evaluation and research processes.

The present study attempted to investigate 1) whether students taught using this approach were able to correctly conceptualize aspects of the particle concept, and 2) whether they could explain phenomena using correctly the particle level. It was thus possible to examine whether students' preexisting conceptions continued to be present in their arguments, and also to determine both the kind of preconceptions present and the possible reasons for their persistence after instruction. We could also examine whether and how this kind of action research was beneficial for developing a cooperative curriculum project within the Participatory Action Research paradigm.

This paper describes an interview study carried out by an action research teacher using seventh-grade students from four different grammar schools (age range 12-13), who had been taught by other teachers in the same action research group. The lessons addressed the particle concept, respective explanations of the states of matter and their changes, and solubility. They took place about 6 months prior to the collection of data, but the lessons concerning chemical reactions took place in the middle of this teaching sequence (about 3 months prior to the collection of data). Volunteer students from each group were selected for the interviews. From the volunteers, the respective teachers selected two pairs of students, one pair characterised as being 'high achievers' and the other as 'low achievers'.

The decision to conduct interviews with pairs of students rather than with individuals alleviated teachers' concerns that students, especially "low achievers", might 1) provide only short, superficial answers to the interview questions and 2) might possibly feel uncomfortable in the interview situation. The teachers expected that the necessary interaction between the students in each pair might make the interview more interesting and frank and also avoid students' feelings of isolation in the assessment situation.

Interviews were conducted with 8 pairs of students. They followed interview guidelines and were conducted as semi-structured, content-focused interviews. The interview guidelines were initially suggested by the interviewer, but they were extensively discussed and modified within the research group. They were also pre-tested by the interviewer with students from his own learning group and modified accordingly. The key

Table 3. Features of the interview guide*

Q1:	What do you know about matter and its structure?
Q2:	Think about wood burning in a fireplace. Describe and explain what will happen!
q2.1:	If there is an argument based only on the macroscopic level: Which other characteristics of this phenomenon do you know about?
q2.2:	Imagine you are able to retain all products of a reaction. How do you consider their weight together compared with the weight of all the initial substances?
Q3:	Think about a spoon full of salt, which is put into a glass of water. Describe and explain what will happen!
q3.1:	Which substances will be in the glass at the end of the process?
q3.2:	Explain the phrase 'Water has become salty'.
Q4:	How do we recognise chemical reactions?
q4.1:	If a characterisation is based only on the macroscopic level: Which other characteristics of chemical reactions do you know about?
q4.2:	If there is a characterisation based only on the particulate level: Which other characteristics of chemical reactions do you know about?

* Q: Key question of the interview; q: Supplementary aspects to be introduced if not mentioned by the students

features and supplementary features of the interview guide are given in table 3.

Each interview lasted for about 15 minutes. The interviews were audio-taped, subsequently transcribed and then analyzed in cooperation with researchers from the university. Evaluation was guided by ideas of qualitative content analysis (Mayring, 2000) and addressed the following key questions which were set forward by the research group:

- Do students consider the particulate level in their explanations when they are asked open-ended questions concerning macroscopic phenomena without any prompts from the interviewer?
- Do students express connections between the macroscopic and the particulate level in their argumentation? Is this connection meaningful and correct initially or only after any prompts?
- Which aspects/concepts from the particulate level are correctly applied and which commonly-held misconceptions appear in students' argumentation?

Finally, both the data and results were discussed within the action research in an attempt to address the following questions:

- To what extent can such small-scale action research studies be used to evaluate students' learning?
- What are the implications of small-scale research studies on curriculum development within action research projects?
- What are the effects, if any, of the present study on the members of the participatory action research group?

RESULTS AND DISCUSSION

Students' Knowledge about the Particle Level

Table 4 shows an overview of students' ideas about the particulate level of matter. All students, including the low-achieving ones, were able to recall their knowledge about the particulate level. Among the low-achieving students, recall of relevant information concerned both stating that matter is made up of particles and giving several details, e.g. aspects from explaining changes in the state of matter. High-achieving students also made reference, without any prompting, to the relationship between the particles themselves and the atoms and to the movement of particles and their changes during chemical reactions. Only some of the high-achieving students made reference to the empty spaces between the particles or the relationships and differences between macroscopic and sub-microscopic changes.

Evidence in table 4 also indicates that students did not really comprehend all their memorized knowledge. An excerpt from the discussion between two low-achieving students concerning mass conservation exemplifies this situation:

I: But what about the mass?

2L2: I believe it becomes smaller.

2L1: No, the mass is not getting smaller, I believe. I read in a book that after a chemical reaction there is just as much as before and that only colour, shape, and so on changed a bit.

I: Do you believe what you read?

2L1: Well, actually only a little bit. I cannot imagine that ... well, that everything consists of particles. I have asked my mother and my father, whether I also consist of such particles. And then they said yes. I can´t really imagine that.

I: Student 2 – What do you think?

2L2: I am not sure. I cannot imagine that either. When there is oxygen in the room … now and then this chemical reaction. I always think that it becomes smaller, because the oxygen is somehow gone, but also creates a new form. Then I don´t know if the mass stays the same.

(Learning group 2, students achievement considered by the teacher as regularly below the average, I: interviewer, 2L1: student 1, 2L2: student 2)

High-achieving students could easily explain states of matter and their respective changes as indicated in the following excerpt:

I: What do you know about the structure of matter?

2H1: That it consists of particles.

2H2: That a substance always consists of small particles, no matter what the substance is, and that the particles of a substance can be transformed to different particles during a chemical reaction. […] A substance can also exist in different states of matter (liquid, solid, or gaseous), and the particles stay the same […]

I: What else do you know about the small particles?

2H1: They are responsible for the states of matter. When a substance is in liquid form, then the particles are a little bit further apart from one another than in the solid state, and when they are in solid state, then particles move only a little bit and are very close to each other. In gaseous state, particles are much further apart from each other, all mixed up, and flying around.

(Learning group 2, students achievement considered by the teacher as regularly above the average, I: interviewer,2H1: student 1, 2H2: student 2)

Table 4. Overview of the students' answers*

	1L	1H	2L	2H	3L	3H	4L	4H
What do you know about the structure of matter?								
All substances are formed of particles. Particles are different for different substances.	X	X	X	X	X	X	X	X
States of matter are related to the movement and the distance of particles.	X	X		X	X	X	X	X
Particles are in continuous motion.				X	X		X	X
Matter can change through chemical reactions.	X			X		X	X	
The particles are very small and invisible. They can only 'be made visible' by Scanning Tunneling Microscopy.	X			X				
What happens if wood burns in a fire place?								
Burning of wood is a chemical reaction.	X	X	X	X	X	X	X	X
New substances are formed.	X		X	X	X		X	
Wood reacts with oxygen forming 'wood oxide' (or carbon dioxide, etc.).	X			X	X	X	X	
New substances can be identified due to their properties.	X		X	X		X		
Particles from wood change into different particles.	X	X	X	X		(I)		X
Total mass of the products:								
is bigger.	X	X						
equals the mass of reactants.	(I)			X	(D)	(D)	X	X
is smaller.			X		X	X		
What happens if a spoon of salt is put into a glass of water?								
Dissolution of salt in water is a physical change.	(I)	X	X	X	(I)	X	(I)	X
The particles do not change. Particles are still there, But, the particles are too small to be seen			X	X		X		X
The particles move away from each other. They are distributed between the water particles.		X	X	X	(I)	X		X
The movement of water particles is the driving force for dissolution.				X		X		X
Dissolution of salt in water is a chemical reaction. A new substance is formed. Salt and water particles combine into new particles.	X						X	
How do you explain the phrase 'the water became salty"?								
A new substance is formed.	X						X	
The salt particles are distributed within the water particles.		X	X	X	X	X		X
How do we recognize a chemical reaction?								
Two initial substances form *one* new substance. The new substance can be recognized by its new properties. (Cases were more than one product is formed were not described.)	X	X	X	X	X	X	X	X
Particles change. Initial particles combine and form new particles with new properties.	X	(I)	(I)	X		(I)	X	X
During chemical reactions thermal energy is set free to the environment through an exothermic reaction.	X	X		X		X		X
Chemical change of matter always is accompanied by energy transformations.				X		X		
What happens if a cake is baked in an oven?								
Baking a cake is a chemical reaction. New substances are formed which can be characterized by their new properties.	X	(D)	X	X		(D)	(D)	X
A change in the particles takes place.	X	(D)	X	X		(D)	(I)	X
Baking a cake is a physical change. The only change is a change in the state of matter (from liquid to solid).		X			X	X	X	

* 1L means learning group 1, lower-achieving students; X = Ideas mentioned by the students, (I) = Ideas mentioned after an additional prompt by the interviewer, (D) = Change in the ideas mentioned after a short discussion without any prompt from the interviewer)

Some of the low-achieving students also provided correct explanations related to a basic understanding of the differences among the states of matter in terms of their constituent particles:

4L1: Different substances can exist in a liquid, gaseous or solid state. Each substance consists of small particles and, depending on the state of matter, the particles are further apart from each other and move faster. And if a substance gets warmer, then its particles move faster and thus expansion occurs.

(L*earning group 4, students achievement considered by the teacher as regularly below the average, I: interviewer, 4L1: student 1,4L2: student 2*).

Chemical Reactions in General

All students began describing chemical reactions as a change of properties. In most cases, this was explained by the formation of a new substance with totally new properties different from the initial substance. Students studied chemical reactions starting with the caramelization and carbonization of sugar, but nearly all of them described chemical reactions as a means of synthesis. For example, they considered a chemical reaction to be a reaction between *two* initial substances forming *one* product (A + B → C) without any other possibilities, such as A → B, A → B + C, or A + B → B + C.

Most of the students tried to explain chemical reactions in terms of the particulate matter. High-achieving students explicitly stated that a change of the constituent particles always occurs in a chemical reaction. In all these cases, the correct connection between both levels of explanation was correctly stated:

2H1: The small particles change.

2H2: The substance does not remain as it used to be. It looks -well- totally different and it has different properties.

I: What is the reason?

2H2: The small particles from different substances combine and form a new substance. They look different then.

I: And what are the results?

2H2: A molecule.

I: And do the particles then still exist?

2H1: Yes, the particles are still the same, but they are linked with each other. And in a physical process, they are also the same, but not linked to each other, only mixed.

*(L*earning *group 2, students achievement considered by the teacher as regularly above the average interview 3, I: interviewer, 2H1: student 1, 2H2: student 2).*

Additionally, in some cases correct explanations were given which included the relationship between the level of discrete particles and their constituent atoms:

I: And what about the particles?

2H1: They don´t change.

I: Don´t change?

2H1: Sure, the particles change, but the atoms don´t. So if you have oxygen, then it always stays an oxygen atom. It´s just that the particles can be put together differently.

2H2: For example, if one had oxygen and magnesium, … No, if one had oxygen atoms and carbon atoms, they combine to form particles of carbon dioxide.

I: So, the atoms don´t change?

2H1: No, but the composition of the particles changes.

(*Learning group 2, students achievement considered by the teacher as regularly above the average, I: interviewer, 2H1: student 1, 2H2: student 2*)

Low-achieving students talked about the particle level only after prompts from the interviewer. Some of them tried to refer to the particle level when making the distinction between chemical reactions and physical processes. In the following excerpt, two low-achieving students considered baking a cake a physical process, but then changed their ideas and correctly considered the baking process a chemical reaction.

4L1: I´d say it´s a physical process. Only the state of matter changes, it turns from liquid to a solid. The taste stays the same.

4L2: The properties of the substance actually don´t change.

4L1: Maybe, it is not a chemical reaction then.

I: You have to prove that.

4L1: There are the initial substances, e.g., milk, eggs, sugar and so on, plus activating energy that would be the heat from the oven. Well, and out of that it becomes a substance, which includes the initial substances together, but is something totally different. So that would be a chemical reaction.

I: How could you notice it?

4L2: Maybe through the little particles, if they changed. If yes, then it is a chemical reaction. If not, then it is a physical process.

(Learning group *4, students achievement considered by the teacher as regularly below the average, I: interviewer, 4L1: student 1,4LS2: student 2).*

In some cases, students also gave wrong explanations. For example, in one interview with two low-achieving students, the pupils stated that properties change because chemical reactions are always related to some kind of combustion. In another interview, low-achieving students mentioned that chemical reactions are always not reversible. In almost every interview, transformations of energy during a chemical reaction were mentioned and a lot of correct ideas were presented, but students considered all reactions to be exothermic. They also stated that activating energy was always necessary, and that the initial substances should be heated or ignited for any chemical reaction to occur. Students´ discussions and ideas resemble those discussed by Boo (1998).

Dissolving Salt in Water

All high-achieving students except for one, provided a correct explanation of the process of dissolving salt in water and also made correct reference to the particulate level.

I: Describe the process when a spoon of salt is put into water.

2H1: At first, there is a small hill of salt, when it is put into water. And when one accelerates the process, for example, by shaking the vessel, then they mixed up, that is, the salt mixes with the water. And one cannot see the salt particles anymore, because they spread out into the water. And one only can taste the salty water. The process is similar to dissolving sugar in tea. Again, you don´t see the sugar anymore, you can only taste that the tea is sweet.

I: And why can´t we see the sugar or its particles anymore?

2H1. Because it dissolved.

I: Then the particles are gone?

2H1: No, they aren´t gone.

2H2: They still exist.

2H1: They exist.

I: But what has happened to them, because you said they dissolved?

2H2: But they are still there.

2H1: Yes, they are still there. If one can taste, they are still there of course.

I: Have the particles been changed somehow?

2H1: No, they have only spread out.

(Learning group 2, students achievement considered by the teacher as regularly above the average, I: interviewer, 2H1: student 1, 2H2: student 2)

Some low-achieving achieving students also offered good explanations for the process of dissolving salt in water:

2L1: Well, the salt dissolves slowly, because the particles of water are in motion all the time, and then they shove in between the salt particles. And then it´s dissolved slowly. … until all the salt is finally dissolved in the water.

(Learning group *2, students achievement considered by the teacher as regularly below the average, I: interviewer, 2L1: student 1, 2L2: student 2)*

Some low-achieving students were not able to correctly explain dissolution on the particle level. They expressed a lot of doubts and mixed several concepts together. Two major misunderstandings were prevalent. 1) The students classified dissolution as a chemical reaction or 2) they confused the understanding of dissolution with melting. In any case, they considered the dissolution of salt in water to be a chemical reaction and stated that the particles combine into "salt-water" particles. It is wrong to consider "salt-water" being a new substance. But, if considering this salt-water to be a new substance, the concept was applied correctly. This has to be connected to the formation of a new kind of particles. In the second excerpt, the student's explanations do not seem to clearly distinguish between the macroscopic and the sub-microscopic level. The students argue that the particles are linked together and that the water takes over the taste of salt. It seems that students were also unable to distinguish between the macroscopic and the sub-microscopic levels when explaining dissolution and that they transferred ideas from melting. The students thought that the salt crystals became smaller and could not be seen anymore, because they melted and therefore turned into a liquid.

I: A spoon of salt is put into water. Describe what happens.

1L1: A chemical reaction will occur.

I: Describe the process!

1L1: Well, when you put salt into water, it dissolves. That means its pieces become smaller. And finally it completely dissolves into the water.

I: What dissolves?

1L2: The salt dissolves.

I: How can you explain this?

1L1: The water particles react with the small salt particles. [...]

1L2: No, I actually believe that dissolution is a physical process. During chemical reactions, something is always burned […]. That´s not the case for a physical process. The smell stays and the particles stay the same.

I: Now you said that it is a physical process, but where did the salt go?

1L2: Maybe the state of matter changed or the pieces became so little that one cannot see them anymore. [...]

(Learning group 1, students achievement considered by the teacher as regularly below the average, I: interviewer, 1L1: student 1, 1L2: student 2)

In another group:

4L2: The salt is put into water and the small particles of salt and water combine. Through this the salt dissolves. And together it becomes a different mixture or substance. [...]

I: And where did the salt crystals go?

4L1: In the water.

I: But they cannot be seen anymore.

4L2: They turn from the solid to the liquid state of matter.

I: Then what does the statement 'water becomes salty' mean?

4L1: Well, salt is salty. Water doesn´t taste like anything really and when salt is added, then the salt crystals are taken apart into such little particles that they link with the water particles. And the water just takes over the taste of the salt particles.

(Learning group 4, students achievement considered by the teacher as regularly *below the average, I: interviewer, 4L1: student 1, 4L2: student 2).*

The Combustion of Wood in a Fireplace and the Principle of Mass Conservation

In all cases, combustion was classified as a chemical reaction. Among the low-achieving students, the explanation started at the phenomenological level and students did not make any reference to the particulate level without being prompted to do so. The high-achieving students started from the phenomenological level and progressively provided explanations based on the particulate level without any further comments from the interviewer, as can be seen from the following excerpt:

I: Wood is burning in a fireplace. What is happening?

1H1: A chemical reaction, I guess. When it´s burning, then it is a chemical reaction, because then the fire needs oxygen.

1H2: It could be explained as follows: Wood and oxygen are actually combined and thus 'wood-oxide' or something like that is formed […] I also think that a chemical reaction takes place, because the particles change while wood is burning. And after it is totally burned, the wood looks entirely different and has a quite different appearance. It also smells differently and, well, the particles themselves have been transformed.

(Learning group 1, students achievement considered by the teacher as regularly above the average, I: interviewer, 1H1: student 1, 1H2: student 2)

The principle of the conservation of mass proved to be difficult for both the low- and high-achieving students. Some of them were able to mention the principle of conservation of mass but did not really accept its consequences.

I: How heavy are the resulting products in comparison *with* the initial substances?

2L1: I would guess that the mass is less.

2L2: It stays the same, if wood is burned in fire. Well, it stays as much as it was at the beginning, but it becomes crumbly. And then it changes to a black color.

I: But what about the mass?

2L2: I believe it becomes smaller.

2L1: No, the mass is not getting smaller, I believe. I have read in a book that, after a chemical reaction, there is just as much as before. Only that color, shape and so on changed a bit.

I: Do you believe in what you have read?

2L1: Well, actually only a little bit. I cannot imagine that.

(Learning group 2, students achievement considered by the teacher *as regularly below the average, I: interviewer, 2L1: student 1, 2L2: student 2)*

Even among the high-achieving students, problems in understanding were evident. Only two high-achieving pairs applied the law of the conservation of mass correctly and without further prompts. One pair came to a correct explanation within their discussion. But one high-achieving pair of students did not come to the correct solution, because the students did not know whether conservation of mass was related to all initial substances and products, or only to those existing in a solid state. In their explanations, they stated that the mass of the products was bigger when considering that 'wood-oxide' was formed:

I: How heavy are the resulting products in comparison with the mass of the initial products?

1H1: Actually the result is heavier. One also has to weigh the resulting substance. Mostly oxygen adds to it and one usually counts the gas, too.

I: And when everything is taken into account?

1H1: Then it is heavier, because the oxygen adds to it.

(Learning group 1, students achievement considered by the teacher as regularly *above the average, I: interviewer, 1H1: student 1, 1H2: student 2)*

Problems were also evident when the concepts of volume, mass, and density were not well understood and sufficiently differentiated:

I: How heavy are the resulting products in comparison with the initial substances?

3L1: I believe it is less, it is less, definitely.

3L2: …and lighter.

3L1: …yes lighter.

3L2: There is already a gas at the end.

I: Imagine, you could catch all of the resulting products.

3L1: I believe, the volume is bigger afterwards, because yes… oh no, the oxygen is being consumed - I don't know.

3L2: Actually, it always stays the same during a chemical reaction.

3L1: But actually a chemical reaction changes the properties of matter.

3L2: …but when two substances.

3L1: No, if it is a closed system, the mass stays the same.

3L2: If one would catch everything and knows what one put in, then it is the same.

I: So, if you have a big room that could be weighed and you had the fireplace and the oxygen in the room. Then it stays the same, you think?

3L1: Well, the volume does. But the weight? I believe, air is not as heavy as a piece of wood. But, I don´t really know that.

(Learning group 3, students achievement considered by the teacher as regularly below the average, I: interviewer, 3L1: student 1, 3L2: student 2)

CONCLUSIONS AND IMPLICATIONS

Some main conclusions can de drawn from the results of the present study. Initially, it is important for us to understand that, in some cases, students provided superficial explanations that seemed to be correct, although they did not really understand the concepts that were involved in their explanations (Gabel & Sherwood, 1983; Lythcott, 1990). But, even low-achieving students were able to deal with explanations on the particulate level when discussing physical changes. In this study, it was evidently clear for all the students that chemical reactions are processes leading to completely new substances which have quite different properties from those of the initial substances. At the same time, they totally excluded the idea that chemical reactions could only result in changes in appearance or be mixtures of the initial substances. For the high-achieving students, the idea of a change into completely new substances was related to a change in the discrete particles that form totally new particles. The low-achieving students were partially able to correctly make this connection, indicating that they needed more scaffolding in constructing the correct relationship between the particle level and the macroscopic level.

Nevertheless, several common alternate ideas were prevalent, while students sometimes tended to overgeneralize the implications of their knowledge. Although the pupils studied and discussed (on the phenomenological as well as on the particle level) chemical changes where more than one substance was formed from one initial substance (carbonising sugar), chemical reactions were consistently, exclusively categorized as reactions starting with two initial substances and leading to one product. Students always considered chemical reactions to be exothermic, although they learned and differentiated between endothermic and exothermic reactions. Some students also continued to face difficulties in correctly differentiating chemical reactions from physical processes both at the phenomenological and the particle level.

The seemingly simple principle of the conservation of mass proved to be extremely difficult for students. The main issue was correctly identifying which substances to take into account. It was, however, encouraging to identify totally- (or nearly-) correct explanations at the particle level for both chemical and physical changes after one year of introductory chemistry lessons. From this perspective, the adopted approach seems to be more effective than other previously-implemented teaching approaches. Empirical data on learning the particle concept in authentic classroom situations does not exist for chemical education in Germany. The idea of introducing explanations of particulate matter in introductory chemistry courses is not unanimously accepted among the people responsible for textbooks and syllabi in Germany. Even if it were so, teaching methods and practices differ extensively.

All data and interpretations were discussed within the action research group. The practitioners in the group believed that it was beneficial to get feedback about their teaching. The teachers themselves felt that they were becoming more aware of the problems concerning matter and its properties. They felt that most of the problems were closely related to recognizing and explaining chemical change. Although this has been described in research literature (e.g., Krnel et al, 1998) and was extensively discussed with teachers, most of them did not take this aspect into serious account, and it was not connected to their own teaching experiences. Thus, after receiving feedback about their own practice from the interviews, they recognized the need to change their teaching. They more thoroughly wanted to include discussions about the concept of matter and about relevant properties of matter (not of objects) in their teaching. The teachers intended to develop guidelines with their students for dealing with chemical properties. These guides should allow the distinction between 'things' from the category of matter and 'things' from the category of 'not matter.' They should provide help in selecting the properties which are good for recognizing chemical reactions from those that are not good, respectively, and should to be taken into careful consideration (Leerhoff et al., 2002a, 2002b).

Also, the principle of conservation of mass was considered to be a major problem. Although all teachers mentioned that they had discussed the principle of the conservation of mass, they reflected that they had not recognized the importance of this principle for students' understanding of chemical reactions. The group now decided to more thoroughly include discussions and experimental work in their future teaching about the principle of the conservation of mass. They decided to put experiments into their teaching repertoire where iron wool or carbon is combusted with oxygen in a closed glass flask. This was recognized as potentially better for an understanding of the principle of conservation of mass and also for illustrating the role of gaseous compounds in chemical reactions. A more detailed discussion about particle explanation and its relation to the principle of conservation of mass was also considered to be really helpful. This seems to be related to the idea that the discrete particles themselves are not conserved but instead their building units, the atoms, are. A sufficient development of the concept of density also seems to be a prerequisite for recognising and characterising chemical changes more effectively.

Most of the described results have already been published, but the current results do not stem from the 'ivory tower' of research, but instead from authentic classroom situations. Thus, these results, despite their limited scope and generalizability, may have a stronger influence on teachers and their teaching strategies. In reality, the teachers themselves commented that they became more sensitive to their students' difficulties and expectations. There is hope that these experiences made the participants more sensitive towards the need to constantly evaluate the effectiveness of their teaching. This conclusion corroborates similar results reported by Valanides et al. (2003).

These experiences suggest that involving teachers in small scale empirical research can improve their sensitivity to teaching and learning and also promote their professional skills in assessment of and reflection on their own teaching (Eilks, 2003b). Obviously, extensive application of similar studies can foster mutual trust between teachers and researchers and can help overcome misunderstandings and prejudices existing between the practitioners and the research community in education (Huberman, 1993; Altrichter & Gstettner, 1993).

REFERENCES

Altrichter, H., & Gstettner, P. (1993). Action Research: A closed chapter in the history of German school science. *Educational Action Research, 1*, 325-360.

Anderson, B. (1986). Pupils' explanations of some aspects of chemical reactions. *Science Education, 70*, 549-563.

Anderson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). *Studies in Science Education, 18*, 53-85.

Ben-Zvi, R., Eylon, B.-S., & Silberstein, J. (1987). Students' visualization of a chemical reaction. *Education in Chemistry, 24,* 117–120.

Boo, H. K. (1998). Students' understanding of chemical bonds and the energetics of chemical reactions. *Journal of Research in Science Teaching, 35*, 569-581.

BouJaoude, S. B. (1991). A study of the nature of students' understandings about the concept of burning. *Journal of Research in Science Teaching, 28*, 689-704.

Carr, M. (1984). Model confusion in chemistry. *Research in Science Education,* 14, 97-103.

de Vos, W., & Verdonk, A. H. (1996). The particulate nature of matter in science education and in science. *Journal of Research in Science Teaching, 33*, 657-664.

Ebenezer, J. V., & Erickson, G. L. (1996). Chemistry students' conceptions of solubility: A phenomenography. *Science Education, 80,* 181-201.

Eilks, I. (2002). Participatory Action Research within chemical education: A research method and experiences with its application. In: Proceedings of the 2nd International Conference on Science Education, Nicosia (Cyprus), 11-13 November 2002, 156-167.

Eilks, I. (2003a). Students' understanding of the particulate nature of matter and misleading textbook illustrations. *Chemistry in Action, 2003*, no. 69, 35-40.

Eilks, I. (2003b). Co-operative curriculum development in a project of Participatory Action Research within chemical education: Teachers' reflections. *Science Education International, 14*, no. 4, 41-49.

Eilks, I. (2005). Experiences and reflection about teaching atomic structure in a jigsaw classroom in lower secondary level chemistry lessons. *Journal of Chemical Education, 82,* 313-320.

Eilks, I., Leerhoff, G., & Moellering, J. (2002). Was ist eigentlich eine chemische Reaktion? [What in fact is a chemical reaction?]. *Der Mathematische und Naturwissenschaftliche Unterricht, 55*, 84-91.

Eilks, I., & Moellering, J. (2001). Neue Wege zu einem faecherübergreifenden Verständnis des Teilchenkonzepts [New ways towards an inter-disciplinary understanding of the particle concept]. *Der Mathematische und Naturwissenschaftliche Unterricht, 54*, 421-427.

Eilks, I., & Ralle, B. (2002). Participatory Action Research within chemical education. in B. Ralle & I. Eilks (eds.): *Research in chemical education - What does this mean?*, 87-98, Aachen: Shaker.

Fischer, H. E., Klemm, K., Leutner, D., Sumfleth, E., Tiemann, R., & Wirth, J. (2005). Framework for empirical research on science teaching and learning. *Journal of Science Teacher Education, 16*, 309-349.

Gabel, D., & Sherwood, R. (1983). Facilitating problem solving in high school chemistry. *Journal of Research in Science Teaching, 20,* 163–177.

Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students´ alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education*, *25*, 65-95.

Gilbert, J. K. & Newberry, M. (2004). The Cams Hill Science Consortium: An inter-institutional collaborative Action Research project in science education. In: B. Ralle, I. Eilks (eds.) *Quality in practice oriented research in science education*, 53-62. Aachen: Shaker.

Gomez, M.-A., Pozo, J.-I., & Sanz A. (1995). Students' ideas on conservation of matter: Effects of expertise and context variables. *Science Education, 79*, 77-93.

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding Models and their use in science: conceptions of middle and high school students and experts. *Journal of Research in Science Teaching, 28*, 799-822.

Hesse, J. J. III, & Anderson, C. W. (1992). Students' conceptions of chemical change. *Journal of Research in Science Teaching, 29*, 277-299.

Huberman, M. (1993). Linking the practitioner and researcher communities for school improvement. *School Effectiveness and School Improvement, 4*, 1-16.

Johnson, P. (1998). Progression in children's understanding of a 'basic' particle theory: a longitudinal study. *International Journal of Science Education, 20*, 393-412.

Johnson, P. (2000). Children's understanding of substances, part I: Recognising chemical change. *International Journal of Science Education, 22*, 719-737.

Johnson, P. (2002). Children's understanding of substances, part 2: Explaining chemical change. *International Journal of Science Education*, *24*, 1037 - 1049.

Johnston, K., & Scott, P. (1991). Diagnostic teaching in the science classroom: Teaching/learning strategies to promote development in understanding about conservation of mass. *Research in Science & Technological Education, 9*, 193-212.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning, 7,* 75-83.

Krnel, D., Watson, R., & Glazar, A. (1998). Survey of research related to the development of the concept of 'matter'. *International Journal of Science Education, 20*, 257-289.

Lee, O., Eichinger, D. C., Anderson, C. W. Berkheimer, G. D., & Blakeslee, T. D. (1993). Changing middle school students' conceptions of matter and molecules. *Journal of Research in Science Teaching, 30*, 249-270.

Leerhoff, G., Kienast, S., Moellering, J., & Eilks, I. (2002a). Der Stoffbegriff und die Stoffeigenschaften - Zentrale Problemfelder bei der Vermittlung der chemischen Reaktion im frühen Chemieunterricht (Part I) [The concept of matter and its properties – Central fields of problems for teaching chemical reactions in introductory chemistry lessons (Part I)]. *Der Mathematische und Naturwissenschaftliche Unterricht, 56*, 301-304.

Leerhoff, G., Kienast, S., Moellering, J., & Eilks, I. (2002b). Der Stoffbegriff und die Stoffeigenschaften - Zentrale Problemfelder bei der Vermittlung der chemischen Reaktion im frühen Chemieunterricht (Part 2) [The concept of matter and its properties – Central fields of problems for teaching chemical reactions in introductory chemistry lessons (Part II)]. *Der Mathematische und Naturwissenschaftliche Unterricht, 56*, 364-368.

Lythcott, J. (1990). Problem solving and requisite knowledge of chemistry. *Journal of Chemical Education, 67,* 248–252.

Mayring, P. (2000). Qualitative content analysis. *Forum: Qualitative Social Research*, 1 (2). Retrieved from the World Wide Web on 01/02/2002 at www.qualitative-research.net/fqs.

Meheut, M., Saltiel, E., & Tiberghien, A. (1985). Pupils' (11-12 year olds) conceptions of combustion. *European Journal of Science Education, 7*, 83-93.

Nakhleh, M. B. (1992). Why some students don't learn chemistry. *Journal of Chemical Education, 69*, 191-196.

Novick, S., & Nussbaum, J. (1978). Junior high school pupils' understanding of the particulate nature of matter: an interview study. *Science Education*, *62*, 273-281.

Pfundt, H. (1982). Untersuchungen zu den Vorstellungen, die Schüler vom Aufbau der Stoffe entwickeln [Investigations of the concepts students develop about the structure of matter]. *Der Physikunterricht, 26*, 51-65.

Scott, P. H., & Driver, R. H. (1998). Learning about science teaching: Perspectives from an action research project. In B. J. Fraxer & K. G. Tobin: *International Handbook of Science Teaching*, 67-80, Dordrecht: Kluwer.

Solomonidou, C., & Stavridou, E. (2000). From inert object to chemical substance: Students' initial conceptions and conceptual development during an introductory experimental chemistry sequence. *Science Education, 84*, 382-400.

Stavridou, E., & Solomonidou, C. (1998). Conceptual reorganisation and the construction of the chemical reaction concept during secondary education. *International Journal of Science Education, 20*, 205-221.

Stavy, R. (1990). Children's conception of changes in the state of matter: from liquid (or solid) to gas. *Journal of Research in Science Teaching, 27*, 247-266.

Taber, K. S. (2001). Building the structural concepts of chemistry: some considerations from educational research. *Chemistry Education: Research and Practice in Europe, 2*, 123-158.

Valanides, N. (2000a). Primary student teachers' understanding of the particulate nature of matter and its transformations during dissolving. *Chemistry Education: Research and Practice in Europe, 1*, 249-262.

Valanides, N. (2000b). Primary student teachers' understanding of the process and effects of distillation. *Chemistry Education: Research and Practice in Europe, 1*, 355-364.

Valanides, N., Nicolaidou, A., & Eilks, I. (2003). Twelfth-grade students' understanding of oxidation and combustion - Using Action Research to improve teachers' practical knowledge and teaching practice. *Research in Science & Technological Education, 21*, 159-175.

Witteck, T., & Eilks, I. (2006). Max Sour Ltd. – Open experimentation and problem solving in a cooperative learning company. *School Science Review,* 88/323 (2006), 95-102

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Slovakian Students' Attitudes toward Biology

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Students' attitudes toward science significantly alter their achievement in science. Therefore, identification and influence of attitudes became to be an essential part of educational research. This study has been initiated by the idea that; research in students' attitudes toward science often involves science in general, but particular disciplines like biology or chemistry have been overlooked. Thus, this study is about Slovak students' attitude toward biology through six dimensions; interest, career, importance, teacher, equipment and difficulty. The study used a 30-item Biology Attitude Questionnaire (BAQ) to measure students' attitudes toward biology education. The data were obtained from 655 secondary school students attending eight typical elementary schools in Slovakia. Multivariate analysis of covariance (MANCOVA) revealed a negative effect of age whereas the effect of gender was not significant. Univariate results, on the other hand, indicated that there is a significant interaction of students' interest in relation with grade and gender. One of the findings of the study is that, students' attitude toward biology teacher is strongly affected by teacher identity. This can be taken as a hint for future research. That effect of teacher should be included as a parameter to be considered for the studies related to student attitude.

Keywords: Learning Attitude, Biology Education, Student, Slovakia

INTRODUCTION

The quality of education that teachers provide to student is highly dependent upon what teachers do in the classroom. Thus, in preparing the students of today to become successful individuals of tomorrow, science and mathematics teachers need to ensure that their teaching is effective. Teachers should have the knowledge of how students learn science and mathematics and how best to teach. Changing the way we teach and what we teach in science and mathematics is a continuing professional concern. Efforts should be taken now to direct the presentation of science and mathematics lessons away from the traditional methods to a more student centered approach.

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Understanding of students' attitudes is important in supporting their achievement and interest toward a particular discipline. Students' attitudes toward science have been extensively studied (Dhindsa & Chung, 2003; Osborne, Simon, & Collins, 2003), but research was initially focussed greatly on science in general (Dawson, 2000) and less attention was addressed to particular disciplines like biology, physics or chemistry (Salta & Tzougraki, 2004). This can partly camouflage students' attitudes because science is not viewed as homogeneous subject (Spall et al., 2003).

In general, students' attitudes toward science decrease with age (reviewed by Ramsden, 1998; Osborne, Simon, & Collins, 2003), boys show more positive attitudes toward science than girls (Simpson & Oliver, 1985; Schibeci & Riley, 1986; O'Brien & Porter, 1994; Francis & Greer, 1999) and more negative attitudes are associated with the physical sciences rather than biological sciences (e.g. Spall, Barrett, Stanisstreet, Dickson & Boyes, 2003; Spall, Stanisstreet, Dickson & Boyes 2004). Keeves and Kotte (1992) and Jones, Howe and Rua (2000) showed that, unlike chemistry or physics, girls showed more positive attitudes toward biology than boys. Dawson (2000) was comparing changes in Australian students' interests and attitudes over 20 years reported that, girls' preferences in biology lead in human biology and general biology, but boys were greatly interested in earth sciences. Current study of Baram-Tsabari and Yarden (2005) using method of children's spontaneous questions found that children's interest in human biology increases with age relative to the interest in zoology which showed opposite tendency. Except gender differences, research on UK students' (aged 11 – 16) attitudes showed that attitudes toward biology exhibit different age-related patterns than attitudes toward physics (Spall et al., 2004). Attitudes toward physics became more negative as age of students increases, relative to more positive attitudes toward biology (Spall et al., 2004). In contrast, Stark and Gray (1999) in a large sample of Scottish students found that boys' preferences for science topics shifted from biologically oriented to physics as the age of students increases, while girls' preference for biological topics were less affected by age and relative high. This means that research in biology would explore different patterns in attitudes related with gender and/or age than other science courses. All factors reported above including basic factors such as such as effects of teacher, parents or environment (George & Kaplan, 1998; Haladyna & Shaughnessy, 1982) would affect students' attitudes toward biology. However, the effect of teacher is disputable; while Gardner (1975) reported evidence that curriculum and teacher effects on attitudes were slight, other studies suggest that students' attitudes are quite malleable, and that individual teachers can have a major effect on both overall science interests and on more specific topic related ones (Bottomley & Ormerod, 1981; Kelly, 1988). This area, however, still received less attention.

In the present study, we examined Slovak students' attitudes toward biology. Biology as a school subject is traditionally separate from other science courses in Slovakia. This study differs from the other research on students' attitudes (e.g. Stark & Gey 1999; Dhindsa & Chung 2003) in that it examines students' attitudes toward biology, not toward science in general. In addition, there is no study that examines students' attitude toward biology in Slovakia either in national or international level. Thus, this is the first study which examined students' attitude toward biology in Slovakia. Moreover, another feature of this study is that, it promises to fill one of the gaps in the area related to comparing students' attitudes with respect to curricular differences and grades. Therefore, this is a cross-age study of attitudinal changes with respect to learning content between grades 5 – 9 and it contributes to deeper understanding in this area in the related literature.

Purpose of Research

This study was conducted to examine Slovak students' attitudes toward biology with respect to age and gender. The study focuses on the following questions:

1. What are Slovak students' attitudes toward biology lessons?
2. Is there any difference between the mean scores of boys and girls on the six dimensions of the biology attitude questionnaire?
3. Is there any difference between the mean scores of students' of different age classes (or grade levels) on the six dimensions of the biology attitude questionnaire?
4. What implications for biology education can be derived from the results of the study?

METHOD

The study was realized with the elementary school students attending 5th – to – 9th grades. In parallel with the applications in Slovakia, they are attending courses of several fields in biology; the students concentrate on a particular topic in different grades (see Table 1 for more details). This allowed us to evaluate gender differences in particular topics and examine the effect of students' age on attitudinal changes.

Respondents

The data for the current study were obtained from 655 secondary school students (n = 321 girls; 334 boys) attending eight typical elementary schools in Slovakia. Schools were selected from three different regions (all in western Slovakia), expressing similar socioeconomic status. Mean age of the students was 12.99 year. Detailed information about grades and number of students is presented in the Table 1.

Instrument

A 30-item Biology Attitude Questionnaire (BAQ) was used to measure students' attitudes toward biology education (Appendix A). The questionnaire was prepared based on the conditions in Slovakia and according to the related research (Salta & Tzougraki, 2004; Spall et al., 2004). The questionnaire has been prepared according to the biology education application in Slovakia. Thus, the items of the questionnaire reflect the particular topics that students concentrate on different grades. Accordingly, items in the instrument were divided into six dimensions as;

1. Students' interest toward biology lessons (Interest)
2. Students' attitude on the importance of biology for their future career (Career)
3. Students' attitude on the importance of biology lessons (Importance)
4. Students' attitude toward biology teacher (Teacher)
5. Students' attitude toward difficulty of biology lessons (Difficulty)
6. Students' attitude on the use of biology equipment in biology lessons (Equipment)

The questionnaire was independently revised by three biology teachers in order to maintain validity. Selected items were then attached to a five-point Likert scale; ranging from "strongly disagree" to "strongly agree" with "neither disagree nor agree" as the pivotal point of the scale. Positive items were scored from 1 to 5, from "strongly disagree" to "strongly agree," respectively, while negative items were scored in the reverse order.

Analysis

Factorial analysis had been utilized in order to examine the correlation between the items of each dimension. As a result, items revealing low correlation had been excluded. Excluded items were the ones from those dimensions titled, "Teacher", "Equipment" and "Difficulty". Reliability of the remaining 24 items was calculated by means of two different techniques: (a) split-half reliability and (b) reliability of "internal consistency." Guttman split-half coefficient (α = .84), Cronbach's alpha for first (α = .82) and second half of items (α = .74) and Cronbach's alpha for whole test (α = .87) showed values that exceed 0.7, which indicate appropriate reliability (Nunnaly, 1978). The comparison of the reliability test results with related literature (Misiti, Shringley & Hanson, 1991; Salta & Tzougraki, 2004) also revealed that the scale is satisfactory and has an acceptable reliability.

Cronbach's alpha values were calculated for each dimension, they were between 0.69 to 0.36. Although results can be considered as appropriate (Jegede & Fraser, 1989; Fraser, 1989; Francis & Greer, 1999; Dhindsa & Chung, 2003), dimensions with relatively low reliabilities, "equipment" (0.36), "difficulty" (0.46), have been further examined to avoid misinterpretation of the results. Cronbach's alpha for "interest" (α = 0.68), "career" (α = 0.62), "importance" (α = 0.69) and "teacher" (α = 0.62) showed satisfactory reliability.

RESULTS

Students' responses

One-way multivariate analysis of covariance (MANCOVA) was used to examine the effect of gender and age on six dimensions. Scores were defined as dependent variables, age as a covariate and gender as a categorical predictor. It was found that students' attitude toward biology is significantly affected by age ($F_{6,647} = 10.9, p < 0.001$), but not by gender ($F_{6,647} = 1.2, p = 0.3$) (Figure 1). These results remained unchanged even after excluding two dimensions with low reliability (Equipment and Difficulty) from the model. Thus, according to the results, no apparent difference was detected between boys and girls, but there appeared a difference among students with different ages (Table 1 and 2). Furthermore, because age correlates significantly with grade (Pearson $r = .904, p < 0.001$), it can be concluded that, students from various grades have different attitudes.

Students' responses to the questionnaire are evaluated with respect to six dimensions as follows:

Interest

Two-way univariate analysis of variance (ANOVA) had been used to determine particular factors affecting students' interest toward biology. Results revealed that both gender ($F_{1,645} = 8.6, p = 0.003$) and grade ($F_{4,645}$ = 23.62, $p < 0.0001$) are significant factors: Girls and younger students displayed greater interest toward biology lessons compared to boys and elders. There had also been found a significant correlation between gender and grade ($F_{4,645}$ = 2.32, p = 0.056). Tukey's Honestly

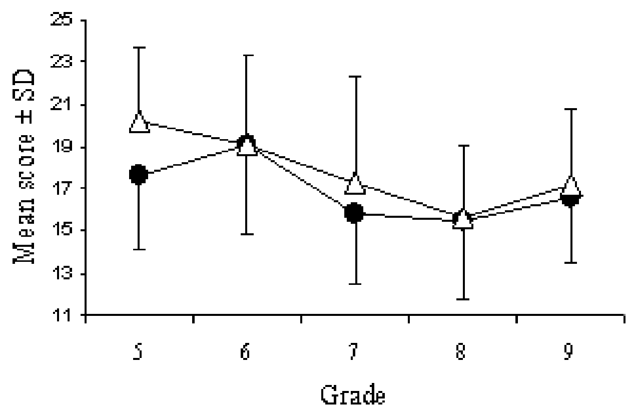

Figure 1. Boys' (solid circles) and girls' (triangles) interest toward biology.

Significant Difference (HSD) post hoc test revealed that fifth (learning botany) and seventh grade girls (learning human biology) showed higher mean score than boys ($p < 0.05$) (Figure. 1).

As far as the frequencies were concerned, it was concluded that, 45% of students was fond of biology, while a significant proportion (21%) did not know. The distribution of positive responses given by the students from different grades were not random ($\chi^2 = 21.6$, $df = 4$, $p < 0.001$), but positive responses were more cumulated in 5th and 6th graders relative to others. A majority of the students (57%), however, do not want to have biology lessons more frequently. Although 16% of the respondents stated that they hate biology lessons, the nature and biology subjects have not been found as "strange" by 68% of respondents. One of the most striking results of this dimension is that, most of the students (83%) enjoy working with living organisms during lessons. As far as the grades are concerned, biology lessons seemed as the most popular among younger students, interest decreases as the grade increases (Figure 2). Therefore, responds for this dimension can be evaluated as that, Slovak students are interested in biology lessons and the interest decreases as they get older. In addition, Slovak students' attitude toward interest in biology lessons differs with gender; girls reveal more interest. Moreover, all items of this dimension significantly and positively correlates with each other, whilst highest mean score (mean = 3.98, SD = 1.2) was found for the item which deals with students' interest of using live animals and plants in lectures.

Career

An univariate ANOVA showed that students' attitudes toward career in biology has been affected by grade ($F_{4, 645} = 21.6$, $p < 0.0001$) and gender ($F_{1,645} = 5.4$, $p = 0.02$): interest in biology career decreased with increasing grade and girls showed greater interest for career in biology compared to boys (Figure 2).

As far as the responses for this dimension were concerned, only 9 % of them would like to be a biologist in the future. Furthermore, older students displayed a significantly higher tendency for refusing biology career (Pearson $\chi^2 = 10.9$, $df = 4$, $p < 0.05$). Interestingly, one fifth (20%) of the students stated that they like to watch films about nature and therefore they would like to think about making a career in biology.

Table 1. Descriptive statistics for the 3 dimensions of the Biology Attitude Questionnaire

Grade (subject)	Interest				Career				Importance			
	M		SD		M		SD		M		SD	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Grade 5 (Botany)	17.6	20.2	3.5	3.5	13.5	15.5	3.4	3.9	18.7	19.9	2.8	2.6
Grade 6 (Zoology)	19.1	19.1	4.2	4.9	12.8	13.9	4.2	4.3	18.2	18	3.4	4.2
Grade 7 (Human Biology)	15.8	17.3	3.3	5	10.9	12.3	3.8	4.1	15.3	17.6	3.9	4.7
Grade 8 (Earth sciences and palaeonthology)	15.5	15.6	3.7	3.5	11	10.7	3	3.7	16.6	16.4	3.7	3.2
Grade 9 (General biology and Ecology)	16.6	17.2	3.1	3.6	11.5	11	3.6	3.4	16.6	16	2.8	2.3

Table 2. Descriptive statistics for the 6 dimensions of the Biology Attitude Questionnaire

Grade (subject)	Teacher				Difficulty				Equipment				N	
	M		SD		M		SD		M		SD			
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Grade 5 (Botany)	12.5	13.4	2.2	1.5	12	12.2	6.2	1.9	11.54	11.55	2.6	2.1	54	45
Grade 6 (Zoology)	12	12.1	2.8	2.4	11	10.9	2.5	2.8	11	11.6	2.5	2.4	87	77
Grade 7 (Human Biology)	10.3	10.7	2.5	3.1	9	9.7	2.6	3.7	10.5	11.1	2.4	2.9	49	58
Grade 8 (Earth sciences and palaeonthology)	10.7	11	2.8	2.5	9	9	2.8	2.9	10.9	10.4	2.3	2	109	89
Grade 9 (General biology and Ecology)	12.5	12.5	1.8	1.8	10.7	10.9	2.7	2.3	9.9	9.9	2.3	2.3	35	53

Twenty seven percent of the students stated that biology knowledge will be important for their career. Items of this dimension were significantly and positively correlated with each other. Detailed inspection of each item showed that lowest scores were obtained for the items that deal with taking their biology teacher as a model for the future life and wishing to be a biologist (mean = 1.8 and 1.9, SD = 1.08 and 1.24, respectively). *T-test* results showed no statistically significant difference between these means; instead a correlation coefficient between these two items was the highest relative to others (Pearson $r = 0.5$). And so, this result suggests that, student' attitude toward taking biology teacher as a model to be a biologist coincides. In other words, students' biology teacher may be one of the items for motivating students' interest in career in biology. We propose that differences in students' ideas toward biologist and biology teachers should be investigated in more details.

Importance

An univariate ANOVA showed that grade ($F_{4,\,645} = 16.39$, $p < 0.0001$) significantly affect students' attitudes toward the importance of biology. According to frequencies, almost half of students agreed that biology is important. As grade increased, on the other hand, percentages decreased (Pearson $\chi^2 = 10.5$, $df = 4$, $p = 0.03$) (Figure 2). Similarly, about half of the students agreed on the item that, they need biology knowledge.

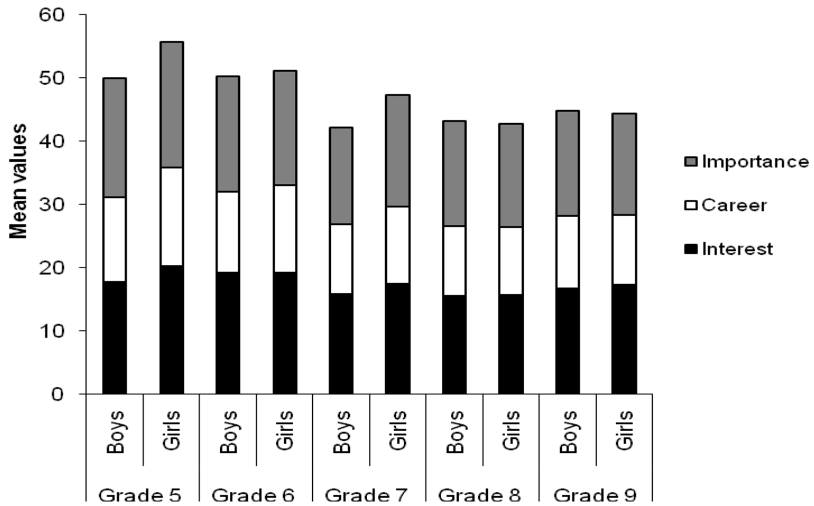

Figure 2. Student responses by gender and grade; dimensions: importance, career, interest.

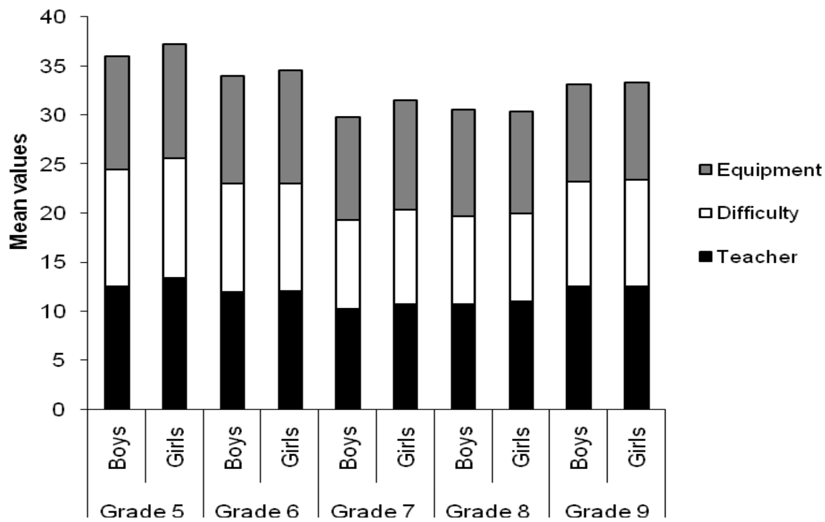

Figure 3. Student responses by gender and grade; dimensions: equipment, difficulty, teacher.

Negative attitudes for this item, on the other hand, had been found for older students (Pearson $\chi^2 = 10.2$, $df = 4$, $p < .05$); more than 50 % of the 9th grade students, for example, showed negative attitudes. Moreover, although 47% of the students agreed that learning biology improves the quality of life, 33 % of them stated that they do not know the answer. All items of this dimension were significantly and positively correlated with each other. Evaluation of the means showed that the highest score was obtained for the item which asks about the necessity of biology knowledge for understanding of other courses (mean = 4.1, SD = 0.1), and that of the lowest was belong to the item which states that, biology is helpful to develop conceptual skills (mean = 2.9, SD = 1.3). Therefore, Slovak students attitude toward the importance of biology can be summarised as that, they believe in the importance of knowledge of biology (perhaps for science), but according to them, biology is not one of the essential issued of their own lives.

Teacher

A univariate ANOVA showed that grade is the only factor (ANOVA, $F_{4,\,645} = 21.1$, $p < 0.0001$) that affects Slovak students' attitudes toward teacher (Figure 3). This relationship, however, seems to be non-linear: while a negative attitude was observed for the 7th and 8th grade students, 5th, 6th and 9th graders displayed a positive attitude.

According to *the* responses given to this dimension, students have positive opinions for their teachers, most of them (71%) like their biology teacher, 62% of them agreed that their teacher motivates them and 78% of them agreed that teacher' judgement on them does not depend on the scores they get. Lower percentages observed especially for 7th and 8th grades were caused by relative higher percentages of "don't know" responses for this dimension. Although the results of this dimension display a *general* picture about the attitude of Slovak students toward biology teachers, results are subject to change for each individual teacher. Testing the attitude of students toward teachers, one-way ANOVA resulted with significant differences between mean scores obtained for each individual teacher ($F_{9,645} = 17.1$, $p < 0.0001$). This indicates that, students' views about teachers differ for each teacher. Moreover, teacher characteristic has a strong effect on students' attitudes; mean scores ranged from 9.7 to 14.1 (15 was the maximum). As a result, this may imply that, individual character of a teacher is one of the important variables to be considered during students' attitudes. All three items from this dimension correlated significantly and both means (3.7 - 3.9) and correlation coefficients (0.29 – 0.39) were of similar value. Therefore, students' attitude toward teacher is related with being motivated by their teachers and not being disregarded even in the case of taking low marks.

Difficulty

Grade (ANOVA, $F_{4,\,645} = 20.5$, $p < 0.0001$) was found as to be the only factor that influences Slovak students' attitudes toward difficulty of biology (Figure 3). Seventy two percent *of* the students defined biology as one of the easier subjects. Distribution of students who defined biology as "easy", on the other hand, was not random (Pearson $\chi^2 = 54.52$, $df = 4$, $p < 0.001$). Sixth grade (learning zoology) and 9th grade students (learning ecology) defined biology as an easy subject, those of 7th (learning human biology) and 8th grades (learning geology /palaeontology), on the other hand, defined it as "harder" compared to other courses and half of the 5th grade students defined biology as "difficult". Moreover, 77 % of the students stated that, they do like the way biology lectures are given in their school. Therefore, the most pronounced result of this item is that, although majority of the Slovak students find biology as an easy course, difficulty rating differs by grade.

Equipment

The two-way ANOVA displayed that grade level ($F_{4,645} = 7.5$, $p < 0.0001$) has a significant effect on the Slovak students' attitudes toward the use of biology equipment. Gender, on the other hand, does not have a significant affect ($F_{4,645} = 0.72$, $p = 0.4$). A majority of the students (72%) stated that they use pictures and drawings during the lectures, but they do not use picture and drawings to prepare for exams. Positive and significant correlation was found between the items of this dimension.

DISCUSSION AND CONCLUSIONS

One of the most pronounced results of the study is that, age is the major factor that impacts students' attitude toward biology for all dimensions. Gender, on the other hand, is found to be effective only for some dimensions. Thus, in general terms, Slovak students have a positive attitude toward biology lessons and biology lessons were most popular among younger students and girls. Students' interest in biology lessons differs with gender; girls have more interest in biology. But the degree of interest decreases as the students get older. The most pronounced reason for students' interest, on the other hand, is that, they are interested in dealing with live animals and plants during biology lessons. The majority of the students believe in the importance of knowledge of biology, but the results displayed that, students do not treat of biology knowledge as one of the issues that is necessary and useful in their daily lives. Although majority of the students find biology as "easy", difficulty rating differs by grade. Teacher characteristics have found to have a significant role on Slovakian students' attitudes toward biology; students take biology teachers as a model for deciding about their career. But, their views about teachers differ according to different teachers. Thus, individual character of a teacher may be one important variable to be work on for the student attitude research. The non-linear differences detected for two dimensions, "interest" and "difficulty", among different grade levels, suggests that attitudes are likely to be influenced by curricula (subject) than age of students' *per se*. For example, biology has been defined as the most difficult by eight graders and the subjects they thought are earth sciences and palaeontology. Interestingly, in contrast with Australian students, where earth sciences were significantly more preferred by boys (Dawson, 2000), boys had low interest in the topic. However, a slight increase of interest and decrease in difficulty has been detected among ninth-graders, which may indicate that interest in biology depends on the topic. Zoology (subject of grade six) was found as to be the most interesting for both sexes. This finding, on the other hand, is closely related with children's natural curiosity about living things. This evaluation can also be supported by the results obtained for the dimension titled "Equipment" that, the students were very much interested in the use of live animals during the biology lessons. Thus, we propose that the use of living organisms would be one of the key factors which can increase students' positive attitudes toward biology. This is consistent with Freedman's (1997) and George and Kaplan's (1998) results that, students' had positive attitudes toward practical settings. The effect of teacher, on the other hand, is another variable which seem to be important. Data presented in this study, suggest that teacher can significantly affect students' attitudes toward biology and this outcome, on the other hand, indicates the need, for further research on this factor. "Teacher effect" is also interesting from another point of view: Based on the current data, it seems that biology teacher is not being distinguished from a biologist. The traditional children's view of a scientist, on the other hand, is that a person dresses a white lab coat, works in a laboratory among test tubes, flasks and bottles and (e.g. Chambers, 1983; Schibeci & Sorenson, 1983; Parson, 1997). Unfortunately, there is no data on students' image of a "biologist". Therefore, further research is needed to understand the students' view about the differences between a "biology teacher", a "professional biologist" and a "scientist". If the evaluation that, Slovak students can not distinguish biology teacher from a biologist, is valid, and if they have a negative attitude toward their teacher, then this may explain why students' attitude toward future career in biology is low.

Educational implications of the study can be summarized as follows. Frequent use of live organism in biology lessons and/or practical works may increase students' interest toward biology. Interest in biology should be developed for boys and older students in particular. Because students showed low interest in career in biology, their interest should be increased perhaps through contact with professional biologists (through science centres) and their ideas about professional biologists and the role of biology knowledge in daily life should be investigated deeply. Biology subjects in the 8th grade should be re-evaluated in terms of learning difficulties and low interest in this topic frequently reported by respondents. Finally, more research should be realised on the subjects like, attitude toward biology teachers and their impact on student's interests and attitudes toward biology. Findings of such studies may significantly contribute to improve biology education in the future.

REFERENCES

Baram-Tsabari, A. & Yarden, A. (2005). Characterizing children's spontaneous interests in science and technology. *International Journal of Science Education, 27*(3), 803-826.

Bottomley, J., & Ormerod, M. (1981). Stability and ability in science interest from middle school to the age of science choices (14+). *European Journal of Science Education, 3,* 329-338.

Chambers, D. (1983). Stereotypic images of the scientist: The Draw-a-Scientist test. *Science Education, 67*(2), 255-265.

Dawson, C. (2000). Upper primary boys' and girls' interests in science: have they changed since 1980? *International Journal of Science Education, 22*(6), 557-570.

Dhindsa, H. S., & Chung, G. (2003). Attitudes and achievement of Bruneian science students. *International Journal of Science Education, 25*(8), 907-922.

Francis, L. J., & Greer, J. E. (1999). Attitude toward science among secondary school pupils in Northern Ireland: relationship with sex, age and religion. *Research in Science and Technological Education, 17*(1), 67-74.

Fraser, B.J. (1989). *Assessing and Improving Classroom Environment. What Research Says to the Science and Mathematics Teachers* (No. 2) (Perth, Australia: The Key Centre for School Science and Mathematics, Curtin University).

Freedman M. P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching, 34*(4), 343-357.

Gardner, P. L. (1975). Attitudes to science: a review. *Studies in Science Education*, 2, 1-41.

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: evidence from NELS: 88. *Science Education, 82*(1), 93-109.

Haladyna, T., & Shauhnessy, J. (1982). Attitudes toward science: A review. *Science Education, 66*(4), 547–563.

Jegede, O. J., & Fraser, B. (1989). Influence of socio-cultural factors on secondary school students' attitudes towards science. *Research in Science Education*, 19, 155-164.

Jones, M. G., Howe, A., & Rua, M. J. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*(2), 180-192.

Keeves J., & Kotte, D. (1992). Disparities between the sexes in science education: 1970-84. In J. Keeves (Ed.), The IEA study of science III. New York: Pergamon, pp. 141-164. .

Kelly, A. (1988). The customer is always right . . . Girls' and boys' reactions to science lessons. *School Science Review, 69*(249), 662-676.

Misiti, F.L., Shringley, R., & Hanson, L. (1991). Science attitude scale for middle school students. *Science Education, 75*(5), 525-540.

Nunnaly, J. (1978). Psychometric theory. New York: McGraw-Hill.

O'Brien, J., & Porter, G. C. (1994). Girls and physical science: The impact of a scheme of intervention projects on girls attitudes to physics. *International Journal of Science Education, 16*(3), 327-341.

Osborne, J., Simon S., & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049-1079.

Parson, E. C. (1997). Black high school females' images of the scientist: expression of culture. *Journal of Research in Science Teaching, 34*(7), 745-768.

Ramsden, J. M. (1998). Mission impossible?: Can anything be done about attitudes to science? *International Journal of Science Education, 20*(2), 125-137.

Salta, K., & Tzougraki, C. (2004). Attitudes toward chemistry among 11th grade students in high schools in Greece. *Science Education, 88*(4), 535-547.

Schibeci, R. & Sorenson, I. (1983). Elementary school children's perceptions of scientist. *School Science and Mathematics,* 83, 14–20.

Schibeci, R., & Riley, J. P. (1986). Influence of students' background and perceptions on science attitudes and achievement. *Journal of Research in Science Teaching, 23*(3), 177-187.

Simpson, R., & Oliver, S. (1985). Attitude toward science and achievement motivation profiles of male and female science students in grades six through ten. *Science Education, 69*(4), 511-526.

Stark, R., & Gray, D. (1999). Gender preferences in learning science. *International Journal of Science Education, 21*(6), 633-643.

Spall, K, Barrett, S., Stanistreet, M., Dickson, D., & Boyes, E. (2003). Undergraduates views' about biology and physics. *Research in Science and Technological Education, 21*(2), 193-208.

Spall, K., Stanisstreet, M., Dickson, D., & Boyes, E. (2004). Development of school students' constructions of biology and physics. *International Journal of Science Education, 26*(7), 787-803.

Weinburgh, M. (1995). Gender differences in student attitudes toward science. *Journal of Research in Science Teaching, 32*(4), 387-398.

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Appendix A: Biology Attitude Questionnaire (BAQ)
Students were requested to respond to the following statements on a Likert five point scale.

Interest toward biology
1. I like biology more than other subjects
7. Nature and biology is strange for me
13. I would like to have biology lessons more often
19. I hate biology lessons
23. The work with living organisms in biology lessons is very interesting

Future career in biology
3. I like watching natural history films; I would like therefore make a career in this in this field
9. Biology knowledge is necessary for my future career
15. My biology teacher is my personal model, I would like to work like he
21. My future career is independent from biology knowledge
28. I would like to be a biologist

Importance of biology
2. Biology helps development of my conceptual skills
8. Biology is not important in comparison with other courses
14. Biology knowledge is essential for understanding other courses and phenomenon
20. Nobody needs biology knowledge
27. The progress of biology improves the quality of our lives

Biology teacher
4. I like my biology teacher
10. Our biology teacher makes us do active work
11. Our biology teacher disregard aspiration of students with bad rating

Difficulty
24. I have often difficulties to understand what we have learn in biology
25. Biology is one of the easiest courses for me
30. I like the way how biology is teaching in our school

Equipment
5. Our biology teacher makes drawings or uses pictures in each practical works
11. We never use any biology equipment
29. When I prepare for biology lesson, I bring to mind equipment that we have used in biology

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Evaluating Gender Differences of Attitudes and Perceptions Toward PowerPoint™ for Preservice Science Teachers

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Microsoft PowerPoint™ has become the generic name used when describing slideware applications. This study analyzed the gender differences of participant attitudes and perceptions of various components of PowerPoint™ presentations. Preservice science teachers (none licensed, mostly undergraduates) viewing PowerPoint™ presentations of science content provided the data. The components of the presentations studied were: text, graphics, the combination of text and graphics, narration, and appropriate use of PowerPoint™ for teaching and learning science content. The affect of animations viewed in prior participant PowerPoint™ experiences was also ascertained. A Kruskal-Wallis test was calculated to analyze the differences between genders for the perceived effectiveness of aforementioned components of PowerPoint™. Results showed a significant difference (H<0.05) for the affect of graphics in PowerPoint™ on gender. Females found the integration of graphics in PowerPoint™ to be a more effective approach to learning science than did males.

Keywords: Gender, Multimedia, Powerpoint, Eye Tracking, Preservice, Attitudes

INTRODUCTION

Siegele (2001) defined slideware as "those glowing overhead presentations given by software salesmen that rarely deliver what they seem to promise." Although there are many slidewxare applications on the market today (i.e., Corel Presentations™, Macintosh Keynote™, etc.), Microsoft PowerPoint™ has become the generic name used when describing slideware applications. In 2002, Brandon-hall.com reported that 66% of the 500 largest companies of the Dow Jones Stock Exchange use PowerPoint™ for e-learning content (Chapman, 2003). Although designed for the corporate sector, PowerPoint™ has increasingly crept into educational settings over the last decade. This trend is consistent with the increased use of PowerPoint™ as a presentation and teaching tool in traditional instructional settings.

As PowerPoint™ is becoming mainstream in educational settings, it is critical for its effectiveness to be studied. This study analyzed the gender differences

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of participant attitudes and perceptions of various components of PowerPoint™ presentations. Preservice science teachers (non licensed, mostly undergraduates) viewing PowerPoint™ presentations of science content provided the data collected through post session survey and through participant eyetracking of the presentation. The components of the presentations studied were: text, graphics, the combination of text and graphics, narration, and appropriate use of PowerPoint™ for teaching and learning science content. Appropriate use of PowerPoint™ was defined in this study as how the media was delivered and for what purpose. For example, is PowerPoint™ an effective delivery method for teaching all aspects of science content? The affect of animations viewed in prior participant PowerPoint™ experiences was also ascertained. The research question thus became: Which components of PowerPoint™ (text, graphics, the combination of text and graphics, narration, and appropriate use of PowerPoint™ for teaching and learning science content) do female preservice teachers perceive to be the most effective for presenting science content? It was hypothesized that females would have more positive attitudes toward text, the combination of text and graphics, narration, and the appropriate use of PowerPoint™ than males, while male preservice teachers would have more positive attitudes toward graphics and animation embedded in PowerPoint™ than females.

LITERATURE FRAMEWORK

The Nature of PowerPoint™

Peterson (2003, p.5) suggested, "In order to excite students about science and mathematics, you must first excite science and mathematics teachers." Technology can be a tool for initiating excitement; if used correctly. Embedding technology into instruction should ultimately be for the improvement of student learning (Osguthorpe, 2003). One of the most commonly used technologies today is PowerPoint™. Tufte (2003), who has arguably performed the most research on PowerPoint™, views PowerPoint™ as entirely presenter oriented; not audience or content oriented. He sees this application as a presenter organizational tool and nothing more than something for the audience to follow.

Alternatively, embedding text, graphics, and video can make a presentation flashy and exciting for the learner. Slide templates allow for variations of text and graphic integration that aim to display the desired content in a varied and meaningful manner. Traditionally, text is considered more suitable for abstract concepts or for asserting assumptions than embedding animations, graphics and/or video. Graphics are more well suited to represent spatial or spatial-temporal relations, particularly in the case of animations (Seufert, 2003).

Tufte (2003) claims that most presentations are projected in front of a large audience and thus inherently the projected graphics are of such low resolution they create incomplete statements by the presenter. If this is true, than why do so many educators use this application in their teaching practice? The answer to this question might be the *Bullet*. PowerPoint™ presentations are inherently driven by bulleted text with occasional images and/or clip art embedded on a slide. Shaw (1998) suggested *Bullet* lists encourage laziness, *Bullets* are usually too generic, *Bullets* have critical relationships unspecified, and *Bullets* leave critical assumptions unstated. Basically, *Bullets* allow disorganized presenters to get organized (Tufte, 2003).

Much of what has been written about the use of PowerPoint™ is of a negative nature. Whether it is for presentations purposes or for instructional purposes, PowerPoint™ is being used, and arguably overused, in both traditional and online settings. Oftentimes asynchronous courses use PowerPoint™ as the sole content communication vehicle (Carrell, 2001). The reality is that technology is being used more competently by more people from all nationalities, age groups, and socioeconomic levels (Murray, 2003) and PowerPoint™, along with the other applications that are part of the Microsoft Office Suite™, is debatably the most universally known technology.

Learning from PowePoint™

Digital learning is the educational approach that integrates technology, connectivity, content and human resources. A collaborative of major corporations and educational organizations reported to congress (CEO Forum, 2000, June) suggesting digital learning is critical if we are dedicated to preparing students with necessary technological and critical thinking skills. In the field of teacher education, it is crucial that instructors understand the ramifications of PowerPoint™ integration as a component of digital learning. Focusing professional development on specific content and how students can learn that content has greater effects on student conceptual understanding and achievement than more general pedagogical activities (Kennedy, 1998). Furthermore, technology and interactions with experts can play a role in providing experiences with real world applications (Petersen, 2003). Teachers need to learn how to most appropriately and effectively integrate technology into their teaching methods. If a teacher models poor use of technology in the classroom, especially in teacher education, then it is likely the student will assimilate those modeled methods and ultimately integrate technology incorrectly into their classrooms.

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In a study that compared learning in classes integrating PowerPoint™ with embedded audio, traditional live classes, and classes that were video based, Carrell and Menzel (2001) found short term learning was significantly higher for audio-PowerPoint™ classrooms.. These results can be argued due in part to the design of the presented PowerPoint™. Students obtain higher level learning from well-designed multimedia presentations than from traditional verbal or text only presentations. This has been shown on test scores and problem solving transfer activities (Mayer, 2001).

A well-designed multimedia presentation can be defined by the level of engagement the students have during a presentation. Mayer (1997) suggests when the learner is engaged in the active process of learning, the learned material is stored in long-term memory. Active learning assumes that learners engage in active cognitive processing which includes attention to incoming words and images, mentally organizing them into coherent verbal and graphical representations, and mentally integrating them with prior knowledge.

Attitudes as a marker for learning

The learner's affective domain has been to a large extent reported throughout recent educational research. "The key to successes in education often depends on how a student feels toward home, self and school" (Simpson, 1994). The instruction a student receives, and often times the technology integrated into instruction, can be a determining factor on satisfaction. Science researchers have given much attention to attitudes because of assumed relationships between attitude and other variables, such as academic achievement (Koballa, 1988). Ajzen (1980) stated the most important reason for studying attitudes is the relationship of attitude to behavior. The behavior a student exhibits during the instructional process can be strongly associated with student satisfaction of a course (Arbaugh, 2000). Most notably, interaction is most influential on student attitudes toward course satisfaction.

When a student is engaged in a highly interactive learning environment, learning and satisfaction usually result (Menzel, 1999). Swan (2001) reported factors such as design clarity, interaction with instructors, and active discussion significantly influenced satisfaction and perceived learning of material. The incorporation of PowerPoint™ into instruction does not inherently promote or discourage interaction. Although the use of PowerPoint™ often promotes discussion, it is primarily a tool that encourages a teacher-centered environment (Tufte, 2003). If PowerPoint™ is used to support active learning, than it must be used in a student-centered environment where interaction between all students and the instructor in prevalent. "Interaction between instructor and student is possibly the most important function of distance learning support" (Wheeler, 2002).

Gender differences with textual and visual stimuli

It is increasingly more noticeable that males enter and persist in science and technology fields then females (Long, 2001). Jakobsdottir (1994) suggested the importance of investigating learning and preferences for graphics and illustrations for gender differences as we enter the digital age. The literature provides evidence the there are gender differences in perceptions of visual stimuli (L. Chanlin, & Chuang, A., 2001). Freedman (1989) suggested females are more concerned with color and color compatibility than males. Males, however, are generally more sensitive to visual stimuli (i.e., graphics, images, charts, etc.) than females (L. Chanlin, 1999).

In a study of sex differences in navigation strategy and geographic knowledge, 90 men and 104 women completed cognitive spatial tests, gave directions from local maps, and identified places on a world map. On the spatial tests, men were better than women in mental rotation skill, but men and women were similar in object location memory. In giving directions, men were more abstract and Euclidian, using miles and north-south-east-west terms, whereas women were more concrete and personal, using landmarks and left-right terms. Older subjects of both sexes gave more abstract Euclidian directions than younger subjects did. On the world map, men identified more places than women did. The data fit a causal model in which sex predicts world map knowledge and the use of Euclidian directions, both directly and indirectly through a sex difference in spatial skills. The age effect, which was independent of sex, supports a developmental view of spatial cognition (Dabbs, Chang, Strong, & Milun, 1997)

MacArthur and Wellner (1996) reported educational practices designated to improve spatial abilities should not be a female-only endeavor. In their study males significantly out performed females on 8 of the 22 spatial structure tasks. However, as with other gender studies, similarities between male and female performances far outweighed any differences. The clinical interview results provided evidence to support the overall poor spatial ability of both males and females.

Butler (2000) reported, males generally have a more positive attitude toward computers, the primary medium for digital images, than females. Finally, gender may play a larger role in the skills of spatial visualization at later ages. However, it is not known whether instruction incorporating spatial visualization will persist in having an effect over time or whether both sexes are affected comparably over time (Smith & Schroeder, 1979). In contrast, Voyer and Voyer (1995) suggested gender

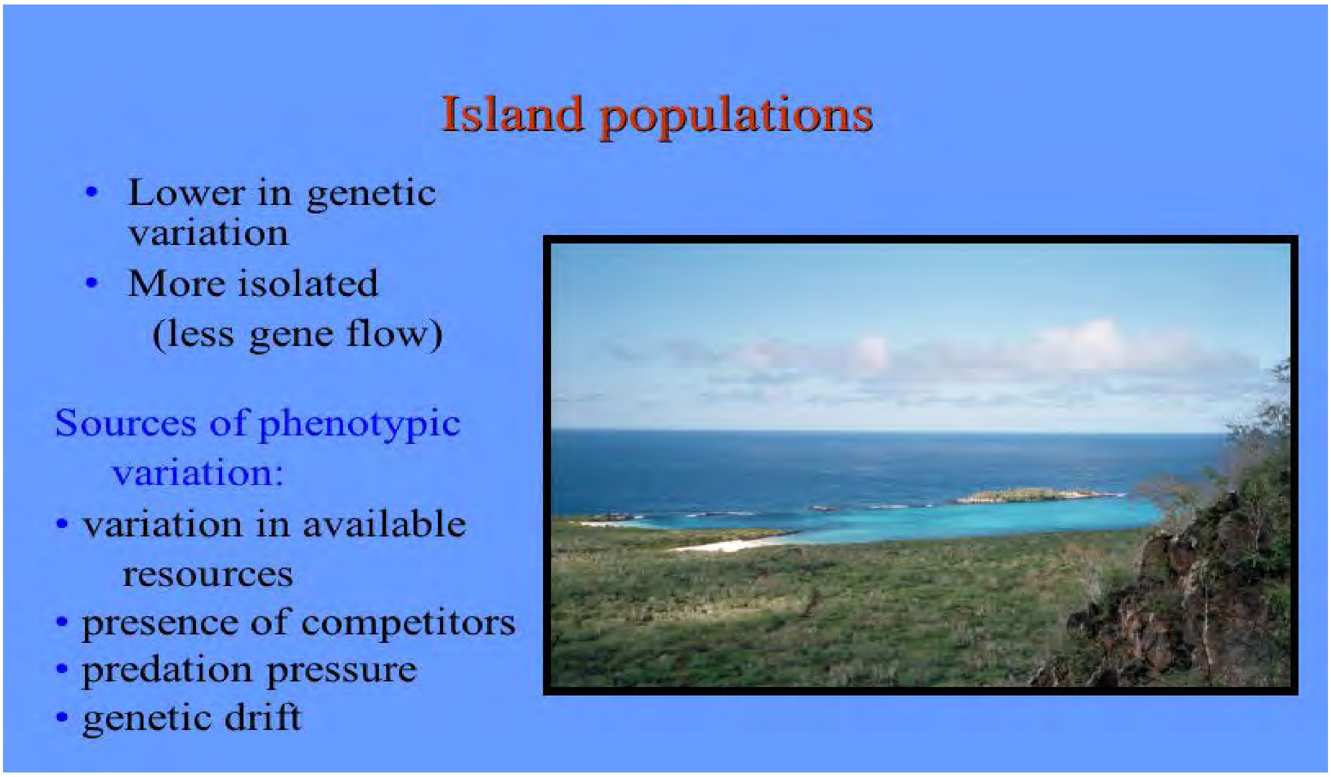

Figure 1. Example slide depicting irrelevant, yet appealing graphic

differences when referring to age depends heavily on the test used.

What follows are the method, results and discussion of the effect PowerPoint has on gender. Age was disregarded based on the Voyer and Voyer (1995) results.

METHODS

Twenty-five preservice teachers enrolled in an introductory science education course were the participants of this study. Fourteen females and 11 males provided gender differences among the participants. Of the 25 participants, 10 were declared science education majors, five declared middle grades science and/or math education as their major, and 10 had undeclared majors but had an interest in science teaching and/or technology education. The sample was stratified across three treatments: 10 participated in the PowerPoint™ without sound treatment, nine participated in the PowerPoint™ with sound treatment, and six participated in the PowerPoint™ embedded in streaming video treatment. The PowerPoint™ presentations were created with a content expert in tropical ecology presenting the material. The crux of the presentation was to offer elementary school teachers an exciting and informative view of recent research of the Galapagos Islands and how the results of this research can inform instruction of ecology and environmental science. The slides were created with interlaced text and graphics. There were specific slides where the graphics and/or animations had no relevance to the text or the audio narration (Figure 1).

Procedures

One aspect of the data collected for this study was through the use of an ASL Model 501 Eye-Tracker that was purchased by funds from the *North Carolina GlaxoSmithKline Foundation*[1]. The eye-tracking equipment allows analysis of individuals interacting with physical models, paper-based materials and all manner of interactive computer-based products. Data collected with this equipment includes: eye fixation paths, video with eye gaze overlay, and numerical data of the pixel location of the point of gaze with statistical calculations. In this study, this equipment was used for data collection of relative to the point of gaze that is suggestive of a subject's reactions to computer stimuli[2]. These data were used as supplement to the quantitative analysis.

Participants entered the eye-tracking lab and after a brief visual acuity test were fitted with the headgear apparatus and their eye movements were calibrated on a computer screen. They then engaged in their given

[1] The authors would like to acknowledge the technical assistance of Bethany V. Smith in data collection, analysis, and facilitating the eye-tracking lab for this study.
[2] http://ced.ncsu.edu/vise/about/aboutthelab.html

PowerPoint™ presentation which was prepared by the lab facilitator prior to the participants' entering the lab. The participants were instructed to proceed through the presentation at their pace. Immediately following the presentation, the participants were asked to complete the attitudinal survey that was presented by the lab facilitator after the headgear was removed.

Data collection

Beyond the data collection through the eye-tracker, participant attitudes were collected via an online survey created in Macromedia Dreamweaver MX™, which allowed for anonymity and easy conversion of the participant responses to the statistical software (SPSS v.11.1) used for analysis. Using the online survey not only allowed for straightforward, instant feedback on a particular session, but it was incorporated with hopes that it would also increase the technology comfort level of the preservice teachers involved. This was not important to the study, but rather as another mechanism for modeling technology integration into the classroom.

The online survey created for this study was modified from the Flashlight Current Student Inventory™. The Flashlight Current Student Inventory™ was designed with a flexible array of survey questions for probing the relationship between new technologies and students' experience learning with them. The survey creator can choose from the inventory that consists of over 5000 items in a database. The items have been shown to be 90+% reliable[3]. The survey for this study chose only those items in the database that were specific to PowerPoint™. Attitudes about PowerPoint™ were ascertained from the participant prior experiences with PowerPoint™, including the presentation on tropical ecology (Appendix A).

Analysis

Responses to items on the post session survey were subjected to a Kruskal-Wallis analysis because N=21 because all of the assumptions of the parametric ANOVA were not met. The attitudinal factors of how participants perceived the effectiveness of PowerPoint™ presentations integrating graphics, text, text and graphics, animation and the pace of narration (if voiceover was used) and perceived appropriate use of PowerPoint™ as a teaching tool were treated as the dependent variables of the analysis that was used to test the null hypothesis of no difference in attitudes for different genders toward perceived science learning among participants who participated in the three treatments of PowerPoint™. Gender was the independent variable in each test for the afore mentioned factors

The eye-tracker data was analyzed descriptively to shed light on the results of the Kruskal-Wallis test. The gaze trail and mean time spent on each slide containing the 6-attiudinal factors for each gender was calculated as a t-test for comparisons between groups which were exposed to a PowerPoint™ with a voiceover narration and a group without narration.

RESULTS

A summary of the mean rank for gender across the 6-attitudinal factors can be found in Table 1. It is quite clear from these data that the variable of graphic integration in PowerPoint™ shows a substantial difference. Table 2 shows the Kruskal-Wallis results illustrating degree of freedom. However, the significance testing in the Kruskal-Wallis suggested only a higher H value (0.018) as compared to the critical value of the Chi-Square for the dependent variable graphic. Females perceived graphics in a PowerPoint™ to be a stronger correlation in that there is one effective approach to learning science than did their male counterparts (see table 2). What follows is a discussion of these results and the implications they have on the educational community using PowerPoint™ as a teaching tool.

The second component to data collection was the use of eyetracking equipment. Table 3 shows the mean time spent on each slide containing the 6-attitudinal factors studied. A t-test was performed to compare a group exposed to voice over narration and a group not

Table 1. Summary of mean rank of gender across the 6-attitudinal factors

	Gender	*N*	Mean Rank
Graphics	Male	9	7.72
	Female	12	13.46
	Total	21	
Text	Male	9	10.17
	Female	12	11.63
	Total	21	
Text & Graphic	Male	9	11.39
	Female	12	10.71
	Total	21	
Animation	Male	9	10.89
	Female	12	11.08
	Total	21	
Pace of Narration	Male	9	12.17
	Female	12	10.13
	Total	21	
Appopriate use of PP	Male	9	11.28
	Female	12	10.79
	Total	21	

[3] http://www.ctlsilhouette.wsu.edu

Table 2. Kruskal-Wallis test for gender differences on attitudes toward PowerPoint™

	Graphics	Text	Text & Graphics	Animaiton	Pace of Narration	Appopriate use of PP
Chi – Square	5.594	.772	.078	.006	.630	0.046
df	1	1	1	1	1	1
Sig.	.018	.380	.780	.937	.428	.830

Table 3. Comparisons of Mean Time Spent on Slides by Gender

Gender	T-G Correlation*	Sound	Mean Time	St. Dev.	Prob > |t|**
M	Low	No	15.49	5.45	.47
F	Low	No	18.29	4.65	
M	Low	Yes	43.55	26.74	.98
F	Low	Yes	43.55	11.83	
M	High	No	19.77	12.12	.78
F	High	No	18.03	4.69	
M	High	Yes	55.54	25.89	.30
F	High	Yes	70.17	1.84	

*Refers to the correlation between the text and graphic on the slide
** Value between males and females with T_G correlation and sound controlled

exposed to narration of the same PowerPoint™. Inspecting the gaze trail from text to graphic showed no significance between groups.

DISCUSSION

The affect of graphics in PowerPoint™ on gender is the focus of this discussion. Freedman (1989) suggested females are more concerned with color and color compatibility than males. The results of this study would support these claims as would the graphics that were embedded into the PowerPoint™ presentation used in this study. An interesting twist to these results is that many of the graphics were irrelevant to the content presented but were colorful and very appealing to the eye (see Figure 1).

Freedman's (1989) findings would suggest that these high-resolution images would be more striking to females and thus have a more profound affect on female attitudes than on males. However, in this study females did not have significantly more positive attitudes than males pertaining to this type of graphic when analyzing the differences of the gaze trail between text and graphic. As can be seen in Table 3, males and females did not spend significantly different amounts of time viewing slides with high-resolution graphics that were not strongly correlated with the text. As Chanlin (1999) reported, males are generally more sensitive to visual stimuli than females. It could be that the male population in this study were more sensitive to the irrelevance of these graphics and therefore thought of them as not effective.

These findings are critical for those who create PowerPoint™ presentations for instructional purposes. Often instructors embed graphics that are irrelevant to the presented content but are appealing to the eye. Unless the combination of text and graphics or the narration of each slide justifies the graphic, the desired transmission of knowledge might not be reached. Understanding the gender population of a class might be the most crucial design component of a PowerPoint™ presentation. Females are more in tune with color and the affect of color and animation is higher with females. If an instructor is trying to excite learning in females, colorful graphics embedded in a PowerPoint™ could be one method to pursue. Conversely, if the intent of the instructor is to excite males, than it is essential that the relevance of the graphics is made obvious.

In science, females are less likely to pursue careers in the physical sciences. One reason for this fact might be that traditionally textbooks and instruction of physical science are in black-and-white or drawn on a chalkboard. Females need to have a voice on layout and inclusion of graphics in textbooks and websites. As a formally male dominated area, publishing expository textbooks needs to consider the use of graphics and the population of who might interact with the textbooks.

As this study confirms, females perceive the use of high quality graphics to be an integral part of effective teaching and learning. As Mayer (2001) suggested, students learn at a higher level from well-designed multimedia presentations than from traditional verbal or text only presentations. Although Tufte (2003) would argue that PowerPoint™ is entirely instructor oriented, the reality is that PowerPoint™ needs to become, and can become, more student oriented. Understanding how different populations of students respond to varying components of PowerPoint™ is a vital piece of the educational puzzle that researchers of instructional technology need to continue to explore.

REFERENCES

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior*. Englewood Cliffs, NJ: Prentice Hall.

Arbaugh, J. B. (2000). Virtual classroom characteristics and student satisfaction with Internet-based MBA courses. *Journal of Management Education, 24*, 32-54.

Butler, D. (2000). Gender, girls, and computer technology: What's the status now? *The Clearing House, 73*(4), 225-229.

Carrell, L. J., & Menzel, K.E. (2001). Variations in learning, motivation, and perceived immediacy between live and distance education classrooms. *Communication Education, 50*(3), 230-240.

CEO Forum. (2000, June). *The Power of Digital Learning: Integrating Digital Content (Year Three Report)*. Washington, D.C.

Chanlin, L. (1999). Gender differences and the need for visual control. *International Journal of Instructional Media, 26*(3), 329-334.

Chanlin, L., & Chuang, A. (2001). The effects of gender and presentation format in computer-based learning. *Education Media International, 38*(1), 61-65.

Chapman, B. (2003). Product shootout: PowerPoint to e-learning. *Training, 40*(3).

Dabbs, J. M., Chang, E.-L., Strong, R. A., & Milun, R. (1997). Spatial ability, navigation strategy, and geogrphic knowledge among men and women. *Evolution and Human Behavior, 19*, 89-98.

Freedman, K. (1989). Microcomputers and the dynamics of image making and social life in three art classrooms. *Journal of Research on Computing in Education, 21*(3), 290-298.

Kennedy, M. M. (1998). *Form and substance in in-service teacher education* (No. research monograph No. 13). Arlington, VA: National Science Foundation.

Koballa, T. R., Jr. (1988). Attitude and related concepts in science education. *Science Education, 72*(2), 115-126.

Long, J. S. (2001). *From scarcity to visibility: gender differences in the careers of doctoral scientists and engineers*. Washington, D.C.: National Academy Press.

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.

McArthur, J. M., & Wellner, K. L. (1996). Reexamining spatial ability within a Piagetian Framework. *Journal of research in science teaching, 33*(10), 1065-1082.

Menzel, K. E., & Carrell, L.J. (1999). The impact of gender and immediacy of willingness to talk and perceived learning. *Communication Education, 48*, 31-40.

Murray, C. (2003). Study reveals shift in digital divide for students, 36-37.

Osguthorpe, R. T. (2003). Blended learning environments: Definitions and directions. *The Quarterly Review of Distance Education, 4*(3), 227-233.

Petersen, R. (2003). "real world" connections through videoconferencing-We're closer than you think! *TechTrends, 44*(6), 5-11.

Seufert, T. (2003). Supporting coherence formation in learning from multiple representations. *Learning and Instruction, 13*, 227-237.

Shaw, G., Brown, R., & Bromiley, P. (1998, May-June, 1998). Strategic stories: How 3M is rewriting business planning. *Harvard business Review, 76,* 42-44.

Siegele, L. (2001, April 14). The Beast of Complexity. *The Economist*.

Simpson, R. D., Koballa, T.R., Oliver, J.S., and Crawley, F.E. (1994). Research on the affective dimension of science learning. In D. L. Grabel (Ed.), *Handbook of Research On Science Teaching and Learning*. New York, NY: Macmillan.

Smith, W. S., & Schroeder, C. K. (1979). Instruction of Fourth Grade Girls and Boys on Spatial Visualization. *Science Education, 63*(1), 61-66.

Swan, K. (2001). Virtual interaction: Design factors affecting student satisfaction and perceived learning in asynchronous online courses. *Distance Education, 22*, 306-331.

Tufte, E. R. (2003). *The cognitive style of PowerPoint*. Chesire, CT: Graphics Press LLC.

Voyer, D., & Voyer, S. (1995). Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. *Psychological Bulletin, 117*(2), 250-265.

Wheeler, S. (2002). Student perceptions of learning support in distance education. *The Quarterly Review of Distance Education, 3*(4), 419-429.

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Appendix A

Prompts for Likert Multimedia Feedback Survey

Section I: Functional Use

Answer the following questions based on your experience with the use of PowerPoint and/or video in THIS session.

1. The total amount of text on a slide is satisfactory.
2. The text on the screen is usually large enough to read.
3. There is so much text on the slides that it is hard to read them.
4. Long passages of text (3 lines or more) on the slides are easy to read.
5. Slide headings help in note taking.
6. Headings are clearer when they are accompanied by images.
7. Headings used alone are understandable.
8. Slide headings are clearly related to slide content.
9. The text on the screen is large enough to read.
10. Slide headings and text are sufficient for understanding.
11. The images on the screen are clear and identifiable.
12. Because the presenter used images to illustrate steps of a process, I understand these processes better.
13. Because the presenter used figures from the text in your slides it is easier for me to reference and review material later.
14. I would understand the lecture better if you showed additional images relevant to course content.
15. Images add interest to the material.
16. Images help me understand concepts.
17. Images help me focus my attention.
18. The use of animations helps me understand complex processes in particular.
19. Motion helps me understand concepts.
20. Motion adds interest to the material.
21. Motion helps to focus my attention.
22. The use of motion is confusing.
23. The pace of slides holds my interest.
24. There was an appropriate amount of time talking about the content of each slide.
25. The pace allowed me to take complete notes.
26. The slides in the video often advanced too quickly.
27. The use of sound with the slides provided a useful demonstration of what I might encounter in actual situations.
28. Audio narrations for the slides made it easier for me to comprehend the material.

Section II: Course Experience

Answer the following questions based on your experience with the use of PowerPoint in traditional classes.

29. Presentations usually cover course material in useful and sufficient detail.
30. Slide content helps me to ask relevant questions.
31. The order of slides usually relates to what I say or ask.
32. The slides seem to determine what we do in class, even when students need something not on those slides, or not in that order.
33. Because instructors used slides to illustrate steps of a process, I understand these processes better.
34. PowerPoint is appropriate for small classes.
35. PowerPoint is appropriate for large lecture sections.
36. I have been able to write notes for review and study from the PowerPoint presentations.
37. Being able to review the slides after class helps to reinforce my understanding of the material.
38. Being able to see slides before class helps me understand the material and content of the class.
39. When I reviewed slides or animation that illustrated a process in action, I could look at the process quickly or one step at a time. That helped me understand the idea.
40. It is generally easy to find and read the presentations from a computer outside the classroom.
41. Instructors generally balance attention to the screen and the class when using slides.
42. I need to interact less with the instructor because course material in slides lecture sessions is clearly presented.
43. I avoid asking for clarification when I don't understand something because I don't want to disrupt the flow of the slide presentation.
44. The slides are so complete; I usually don't need to read the textbook.

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A Case Study of One Student's Metaconceptual Processes and the Changes in Her Alternative Conceptions of Force and Motion

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The aim of this paper was to describe the changes in one student's ideas about force and one-dimensional motion concepts and portray the relevant metaconceptual processes that she engaged in during the implementation of metaconceptual teaching interventions. Metaconceptual processes involves metacognitive processes that are directly acting on or related to individuals' conceptions, mental models or elements of their conceptual ecology. Several types of instructional activities including poster drawing, concept mapping, group debate, journal writing and group and class discussions were used to activate students' metaconceptual processes. The findings of the study indicated that the student changed all of her alternative ideas that were assessed before the instruction with scientifically accepted conceptions following the instruction. The findings also showed that the student engaged in several types of metaconceptual processes ranging from simple awareness of ideas to more sophisticated metaconceptual processes, such as metaconceptual monitoring and evaluation. The findings strengthen the claims about the positive impact of metaconceptual processes on changing students' conceptions of physical world.

Keywords: Conceptual Change, Metacognition, Metaconceptual Processes

INTRODUCTION

In recent years, the importance of metacognitive processes in facilitating the change in students' existing conceptions has been acknowledged by many researchers (Georghiades, 2004; Vosniadou, 2003). In this research metaconceptual teaching interventions that aimed to activate a group of students' metaconceptual processes were implemented. This paper presents the changes in a single student's conceptions of force and motion and describes the metaconceptual processes that she engaged in during her involvement in metaconceptual teaching practices.

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Theoretical Framework

This research rests on two main bodies of literature: conceptual change and metacognition.

Conceptual Change Process

Studies conducted in the field of science teaching and learning clearly demonstrated that students come into classrooms with existing ideas that are different from those accepted by the scientific community and these alternative explanations exist even after formal instruction (Driver & Easley, 1978). Existence and resistance of students' alternative conceptions suggests that learning a new conception does not only involve addition of new information into existing knowledge structure but it also involves a major restructuring in the existing conceptual system (Scott, Asoko, & Driver, 1992). This view of learning attracted the interest of researchers to search for theoretical models to explain the nature of the change process, and develop instructional approaches to promote the change in students' conceptions. .

The Conceptual Change Model proposed by Posner et al. (1982) has been one of the popular theoretical frameworks in science education for several years. This model described the conditions that need to be satisfied for an individual to change his/her ideas, and the components of individual's conceptual ecology. Research studies conducted in the area of cognitive psychology have also proposed theoretical frameworks about the nature of the change in students' conceptions (Vosniadou, 1999). In the mid-1990s many researchers proposed theoretical explanations for what changes in the conceptual change process (Chi, Slotta & Leeuw, 1994; diSessa, 1993; Ueno, 1993; Vosniadou, 1994). According to these researchers, learners' ontological (Chi et al., 1994) and epistemological presuppositions (Vosniadou, 1994), their "self-explanatory" everyday experiences (diSessa, 1993) and the context (Ueno, 1993) plays a significant role in the development of alternative conceptions. For them, in order to experience a change in alternative conceptions learners should compare and contrast their existing conception and new ideas, recognize, integrate and evaluate existing and new conceptions and associated commitments, everyday experiences and contextual factors. These processes assume a learner who is aware of his/her conceptual system, monitors the consistency between his/her existing ideas and information coming from different sources and evaluates the new and existing ideas by providing justifications. Awareness, monitoring and evaluation are the subcomponents of metacognition. Pintrich and Sinatra (2003) stated that the theoretical models proposed to explain the change in students' conceptions make an "assumption about the importance of metacognitive awareness" (p. 432). Several researchers acknowledged the role of learners' metacognitive processes in changing their conceptions (Beeth, 1998; Ferrari & Elik, 2003; Georghiades, 2004; Hennessey, 1999, 2003; Vosniadou, 1994, 2003; White & Gunstone, 1989).

Metacognition and Metaconceptual Processes

Metacognition is a very broad construct that has gained a great deal of attention in cognitive and educational psychology. Although it has been extensively studied metacognition has been described as a "fuzzy concept" (Flavell, 1981, p. 37). It is broadly defined as "one's knowledge and control of own cognitive system" (Brown, 1987, p. 66). It is also described as one's "inner awareness" about one's learning process, what one knows or one's current cognitive state (Hennessey, 2003) and "knowledge about knowledge. Kuhn, Amsel and O'Loughlin (1988) defined metacognition as "thinking explicitly about a theory one holds (rather than only thinking with it)" (p.7). As these definitions suggest, metacognition subsumes three main types of knowledge and processes: (a) one's acquired knowledge about cognition, (b) online awareness of one's stock of information and (c) control and regulation of one's cognitive processes.

Various kinds of knowledge and processes have been identified as metacognitive in their nature. Researchers identified knowledge and processes, such as knowledge about problem solving or reading strategies, monitoring and regulating the execution of those strategies, awareness and employment of heuristics, one's knowledge about the limitations of his/her memory or learning styles as metacognitive (see Brown, 1978; Flavell, 1979; Garner, 1987; Hacker, 1998; Schraw & Moshman, 1995). These knowledge and processes play a role in successfully performing a cognitive task (Hennessey, 2003). However, these domain general knowledge and processes may not bring about a major restructuring in learners' conceptual systems. As the theoretical frameworks proposed to explain the change in students' conceptions suggest, achieving a major restructuring requires metacognitive knowledge and processes that are acting on or related to learners' conceptual system. Since the term metacognition subsumes several types of knowledge and processes it is fruitful to differentiate metacognitive knowledge and processes that are acting on and related to one's conceptual system from other metacognitive knowledge and processes. I use the term "metaconceptual" to refer to metacognitive knowledge and processes that are acting on and related to one's conceptual system. Recently, an increasing number of researchers started to use the term "metaconceptual" to refer to the meta-level thinking processes that are acting on students' conceptions (see, for example, Mason & Boscolo, 2000; Vosniadou, 1994, 2002, 2003; Wiser & Amin, 2001)

Based on the theoretical distinctions among the subcategories of metacognition which are an acquired knowledge about one's cognition, online awareness of one's personal stock of information and one's control and regulation of cognition, metaconceptual knowledge and processes can be classified into four major components: (a) metaconceptual knowledge, (b) metaconceptual awareness, (c) metaconceptual monitoring and (d) metaconceptual evaluation.

Metaconceptual knowledge refers to one's acquired stable and statable knowledge about concept learning and the factors affecting one's concept development. Metaconceptual awareness is one's online awareness of and reflection on existing concepts and elements of conceptual ecology including one's interpretation of experiences, ontological and epistemological presuppositions. Metaconceptual monitoring involves control processes which generate information about one's cognitive state and thinking processes. Metaconceptual evaluation involves processes in which learners make judgmental decisions about the relative ability of the competing conceptions to explain the real phenomenon. Both metaconceptual monitoring and metaconceptual evaluation processes occur during the learners' attempts to learn a conception. Examples to these processes are monitoring the comprehension of conceptions, the consistency between the existing and new conception, the changes in ideas and making comments about the relative plausibility, usefulness and validity of existing and new ideas.

Purpose of the Study

Metaconceptual processes require learners to engage in abstract and higher levels of thinking which is not easy to achieve through formal instruction. In this study, metaconceptual teaching activities were implemented to facilitate students' engagement in the above stated metaconceptual processes. The aim of this case study is to describe the changes in one student's understanding regarding force and one-dimensional motion concepts and portray her metaconceptual activities that she engaged in during the metaconceptual teaching activities. In this paper, I did not intend to prove or disprove the effectiveness of metaconceptual teaching activities, but rather I portrayed a case of metaconceptual processes that took place during the implementation of the metaconceptual teaching interventions and the relevant changes in the conceptions of the student. In that sense, this case study is descriptive and explanatory rather than confirmative.

Case studies are very useful in terms of gaining a deep insight into the learning processes of one student. Case studies are descriptive and inductive in the sense that a researcher may seek to understand a larger phenomenon through close examination of a specific case. Although the metaconceptual teaching interventions covered variety of topics related to force and motion, such as Newton's First Law, Newton's Second Law, Newton's Third Law, friction, projectile motion, gravity, and circular motion, the target case student's ideas and metaconceptual processes were examined within three main topics: definition of force, relationship between force and motion, and Newton's First Law of Motion.

Within the limits of this article, it is not possible to describe every metaconceptual process that the student displayed regarding to every conceptual topics covered by the activities. However, the examples given for these three main topics are representative enough to show the diversity of her metaconceptual processes and the changes in the relevant conceptions.

METHODS AND PROCEDURES

Design of the Study

The metaconceptual teaching activities were implemented in a physics classroom of a high school located in Ohio, in the USA, There were 22 eleventh and twelfth grade students in the class and most of them had not taken a physics course in the past. The student for the case study was chosen so as to span a range of alternative ideas about force and motion and to have the ability to communicate his/her ideas well during the implementation of the study. In doing so, it was aimed to portray metaconceptual processes with content involving a wide range of alternative ideas that changed throughout the instructional interventions. The student was identified by observing students for two months before the instruction related to Newton's Laws started and by examining students' pre-instructional scores on the Force Concept Inventory (FCI). FCI is a systematically developed multiple-choice test designed by Hestenes, Wells and Swackhamer to probe students' commonsense beliefs about force concept and "how these beliefs compare with the many dimensions of Newtonian concept" (Hestenes et al., 1992, p. 142). Within the science education community, it is one of the widely used diagnostic tools in existence for assessing students' conceptual understanding of Newtonian mechanics (Hake, 1998; Henderson, 2002).

Data Sources

The changes in the case student's ideas regarding force and motion concepts and her metaconceptual processes relevant to those ideas were examined by collecting data from multiple sources before, during and following the instructional interventions. The data regarding the case student's metaconceptual processes were derived from the video-recordings of classroom discussions, audio-recordings of group discussions (group discussions about conceptual questions, demonstrations and hands-on experiments, group discussions as students drew posters and explained to each other their concept maps), and journal writings. One-to-one semi-structured interviews were conducted prior to and after the instruction to assess her alternative ideas, areas of confusion, and the gaps in her understanding of force and motion concepts. One of the open-ended questions aimed at exploring how the student defined force and what characteristics she attributed to this concept. The other interview questions involved showing her a series of situations in the forms of pictures, demonstrations, or verbal explanations. She was asked to explain the forces acting on and motion of objects within the context of the provided situations. Many of the interview questions were similar to those used in the clinical interviews conducted in previous research that explored students' conceptual understanding of force and motion (Clement, 1983; diSessa, Elby, & Hammer 2003; McCloskey, 1983). Three of the interview questions were similar to the questions in the FCI (Hestenes, Wells & Swackhamer, 1992). An example for the questions asked during the interviews is provided below:

Example:

Could you describe what happens when I throw this ball as it travels up and then back to my hand in terms of its speed and the forces acting on this ball? [A ping-pong ball was tossed up by the researcher].

Probing Questions:

- Could you describe what happens as it rises? Does it speed up, slow down, or move with a constant speed? Are there any forces acting on the ball as it rises?
- What happens at the peak? Are there any forces acting on the ball at the peak?
- What happens when it is falling down to the ground? What are the forces acting on the ball? Does it speed up, slow down, or move with a constant speed?
- How strong are the forces acting on the ball compared to each other?

Metaconceptual Teaching Practices

In order to facilitate students' engagement in metaconceptual knowledge and processes several types of instructional activities including poster drawing, concept mapping, group debate, group and class discussion and journal writing were employed. At various points throughout the instructional interventions, these instructional activities were blended with demonstrations or hands-on experiments so as they served as domain specific metaconceptual prompts in the form of making predictions and providing explanations about a given situation, comparing and contrasting predictions with what is observed, evaluating existing ideas in relation to the observed data. Laboratory experiments about friction, Newton's Second Law and projectile motion were used without any explicit attempt to facilitate metaconceptual processes.

Poster Drawing. Through poster drawing activity it was aimed to facilitate students' engagement in metaconceptual awareness and metaconceptual monitoring. At the beginning of the instructional interventions, in order to encourage students to become metaconceptually aware of their existing ideas, experiences and relevant presuppositions they were prompted to produce posters about their group's understanding of force concept along with examples from their daily experiences. In order to facilitate students' engagement in monitoring the consistency between their initial understanding and current ideas about force concept, the poster drawn by the students were given back to them near the end of instructional interventions. Students were asked to think about the changes they wanted to make in their initial posters and explain why they want to make those changes. Students were asked to present their initial and final posters to their classmates.

Journal Writing. Journal writing provided students with the opportunity to engage in several types of metaconceptual processes. The journal prompts given to the students encouraged them to step back and reflect on their existing conceptions, examine the reasons why they were attracted to their existing views or information coming from different sources, monitor their understanding and the differences in different views to explain a physical phenomenon, make judgments on the validity of different ideas about a topic under investigation, recognize the limitations of their views, look for consistency among their ideas across different contexts, and monitor the changes in their ideas. Students were also requested to write about their learning of science concepts. For example, they were asked to write about how and under what conditions they change their ideas by drawing upon an analogy between Newton's First Law and changes in their science ideas or to compare the applicability and generalizability of scientific principles and their own ideas.

Examples for the journal prompts given to the students are provided below.

> "Have you changed your mind about the alternative you have chosen for the question about the forces acting on the book? If yes, why do you think your current idea is better than your initial idea? What made you change your initial idea? If no, why do you think the alternative you chose is the best answer for the given question?"
>
> "What were your initial ideas about the forces acting on the ball while it rises up, while it is at the peak of its trajectory and while it falls? Why do you think you hold those initial ideas?
>
> While discussing your ideas about the forces acting on the ball as a group or as a class, did you notice any differences between your ideas and other classmates' ideas? Was any idea that was different from your initial idea attractive to you? Why/ Why not?"
>
> "Examine the consistency of your ideas about the forces acting on objects and the relationship between force and motion of objects across different situations. Group similar situations (in a way that makes sense to you) and compare the consistency among your initial and current ideas within each group. Are your ideas consistent

among similar situations? [As part of this journal prompt, students were given a table in which they were asked to write their initial and current ideas abut forces acting on objects in different situations]."

Group Debate. Group debate activity was employed to help students become aware of their ideas and associated presuppositions about a physical phenomenon, justify their ideas, and evaluate the validity of different views as they discuss their ideas with other students who hold different ideas. Students were asked a conceptual question with multiple alternatives and they were requested to choose one among the several alternatives. Students who chose different responses were asked to explain each other why the alternative they chose was the best explanation for the physical phenomenon presented in the question.

Group and Classroom Discussions. The purpose of using classroom or group discussion activities was to bring diversity of opinions held by the member of the class about a physical phenomenon and their ideas about their learning of science concepts into open. Students were facilitated to describe explicitly their own ideas, the reasons behind their ideas and to compare and contrast among different ideas. Students in groups of three or four were asked to discuss their ideas about a given situation or before performing a demonstration or hands-on experiment. After the group discussion, students summarized what they discussed as a group. The teacher did not introduce the scientific explanation until the students couldn't provide further explanation for the physical phenomenon Examples of the discussion prompts used by the teacher are: "Could you explain what you mean by….?" "David thinks…. What do you think about his idea?" "Do you agree with David?" "Why do you disagree with him?" "Why do you think your idea is better?" "Why do you think so?" "Is it [their observations] different from what you initially thought?" "Do you agree with your group's idea?" "Do you understand what your friend just said?" Students were also prompted to discuss how they learn concepts, why their ideas are different, why is it important to reflect on what they already know, the difference between understanding and believing, and how they know they understand a concept.

Concept Mapping. Concept mapping activity aimed to help students see the relationships among different concepts. Students were provided with a number of terms, such as "$F_{net}=0$," "$F_{net}<0$," "$F_{net}>0$", "constant speed," "at rest," "motion," "acceleration," and "deceleration." They were asked to arrange the terms into a map so that the map represented the relationships between the terms. After they produced the diagrams they summarized their concept maps to other students in their groups.

DATA ANALISYS AND FINDINGS

This section portrays the ideas that Lisa held prior to and following the instructional interventions about force and one-dimensional motion and describe her metaconceptual processes that she engaged in as she participated in metaconceptual teaching practices.

Lisa's Case

Lisa is an eleventh grade student who did not take any physics courses before this class. Lisa took this course because she was planning to take an advanced placement physics course the following year, and she wanted "to learn enough to have a good background" for that course. She did not like memorizing subjects, but she claimed that she learned "best by knowing the 'why' behind a fact." Lisa wants to study chemical or biomedical engineering at college. She was chosen as a case because of her low score on the FCI administered prior to instruction. Out of the 30 items, she was able to correctly respond to 8 items on the pre-instructional FCI, indicating several alternative ideas about force and motion. She correctly answered 27 and 25 items on the FCI administered immediately following and nine weeks after the instructional interventions, respectively.

Lisa's Pre-Instructional Ideas about Force and One-Dimensional Motion

Before the instructional interventions, Lisa defined force as "an action that would act upon an object." Although she used examples in which objects are accelerating as a result of being exerted by a force, Lisa could not differentiate acceleration as the outcome of force from any kind of motion (R denotes Researcher):

R: How do you know that force is acting on an object?
Lisa: Previous experience.
R: What kind of previous experience? What experiences tell you that force is acting on an object?
Lisa: Eventually something will stop and that's because of friction. A ball will drop because of gravity. You push something it will move.
R: All of your examples involve motion. Do you associate force with any kind of motion?
Lisa: Any motion.
R: What about constant motion?
Lisa: Yes.

The excerpt taken shows that, for Lisa, force could create any kind of motion. Although she agreed that force might cause objects to move at constant speed, she did not specify that only balanced forces or having no forces acted upon produced constant speed.

Throughout the interview she displayed no signs of knowledge about the outcome of balanced and unbalanced forces. She had an interesting belief that an object could not move at a constant speed if there was a force acting on the object in the opposite direction of its motion.

R: Is there a way to keep it moving at a constant speed?
Lisa: No. Because you have two forces acting on it.
R: If there are two forces acting on an object do you think that the speed will not be constant?
Lisa: No, the speed won't be constant because the force of your push increases the speed. Then as friction acts more on it, it slows.
R: Okay. What should I do to keep the book moving at a constant speed?
Lisa: Take away friction?
R: Take away friction. I want to move this book at a constant speed from point A to point B what should I do? Other than taking away friction?
Lisa: If you push it harder it's still not going to be constant, the speed is not going to be constant.

For Lisa, the only way to keep an object moving at a constant speed is removing the force acting in the opposite direction of the object's motion. In situations where there were no opposing forces, she held the idea that the objects moved at a constant speed due to a force acquired from the agent to the objects. For example, for her, a ball tossed up in space, where there was no gravity, continued to move at a constant speed even though she thought that the force from the hand was still acting on it.

R: What about the force I used to throw the object up? Is it still acting?
Lisa: Yes.
R: Does it increase, decrease, or stay constant as it moves?
Lisa: Constant.
R: Why do you think it's constant?
Lisa: Because there's no other force acting upon it.
R: What about its speed?
Lisa: Speed is the same [constant].

Another alternative idea that Lisa possessed was her belief that the force in the direction of the object's motion had to be greater than the force in the opposite direction even though the object was moving at a constant speed. She displayed evidence for this belief when she was asked to compare the amount of forces acting on a car and truck moving together at a constant speed.

R: Okay. After a while the car has pushed the truck and they have reached a constant cruising speed, they move at that constant speed together. Do you have any idea about the amount of the forces acting on the truck or the car?
Lisa: The friction is still active on them. The car's force overcomes that.
R: What do you mean by overcomes?
Lisa: The force of the car must be more than the force of friction because they are moving.

Throughout the interview in various situations, Lisa displayed extensive evidence for her alternative idea that objects acquired a force when they were set in motion by an agent. She considered force as an acquired property of objects that moved as result of an agent pushing or pulling them. She made explicit reference to this idea when she was asked the forces acting on a book moving across a table after being pushed by my finger.

R: I push this book across the table from this point to this point. Let's call this point A and this point B, okay? What are the forces acting on the book as it moves from point A to point B? You may draw pictures if you would like to [The researcher pushes a book on a table and let the book slide across the table].
Lisa: Okay. Well you pushed the book. So you're a force and friction slows the book and that's a force and the table prevents it from dropping so that's a force gravity is always pulling down on it.
R: Could you draw a figure showing the forces?[Lisa draws a figure that shows an arrow in the direction of book's motion].
R: Okay, does the force that I used to push the object from point A to point B still act on the book as it moves from point A to point B?
Lisa: Yes, because the book is moving.
R: Does it [force from hand] increase, decrease, or stay constant while it moves?
Lisa: Constant.

In the excerpt above Lisa displayed her belief that the force applied on the book to set it in motion was still being exerted on it even after it lost contact with my finger. For her, the acquired force was responsible for the book's horizontal motion and. did not change but rather stayed constant as the object moved.

For Lisa, there was not only a need for a force to keep the object moving in situations where there were opposing forces but force was also needed to maintain the object's motion in the absence of opposing forces. For example, as shown in the excerpt below, she stated that a book set in motion on a frictionless surface acquired a force that kept it moving at a constant speed. She thought that the acquired force stayed constant throughout the book's motion. It is clear that Lisa did not consider the object's motion as a natural state of objects but rather, for her, there was a need for a force that kept the object moving even in the absence of opposing forces.

R: Okay. Suppose that I push this object, this book on a very smooth surface where there is no friction. What would happen if I pushed the object?
Lisa: It would remain at a constant speed.
R: Will it slow down or increase its speed eventually?
Lisa: No, not unless it come in contact with another force.
R: What forces will be acting on a frictionless surface?
Lisa: You still have gravity and you still have air force which I guess could affect its movement, make it not constant.
R: Is there a force acting on the book other than gravity and an air force?
Lisa: Well it is moving. So it has a force of your push still.
R: Is it still exerting on the book while it's on a frictionless surface?
Lisa: Yes, it's exerting force.
R: Does it increase, decrease, or stay constant while it moves?
Lisa: Stays constant.
R: Why do you think it stays constant?
Lisa: Because there is no force acting against your push.

Lisa's Post-Instructional Ideas about Force and One-Dimensional Motion

Prior to the metaconceptual instructional interventions, Lisa believed that force created any kind of motion. After the instructional interventions, Lisa defined force as "push or pull or an action that causes acceleration." Her definition of force did not involve any type of motion, but she could clearly state that force caused objects to accelerate. Her statements below show how her ideas changed after the instructional interventions.

R: How do you know that forces are acting on an object?
Lisa: You can see it. Like you can if I push a book it'll move. And something has caused that.
R: Ok. Do you think that anything that is moving is being exerted by a force?
Lisa: No, because you can have constant velocity and there will be no force acting on it or balanced forces.

As the above excerpt indicates, Lisa did not associate force with motion anymore. For her, objects could move at a constant speed even when there were no forces acting on them.

Previously, Lisa was also unable to differentiate the outcome of balanced and unbalanced forces. She held the idea that objects could not move at a constant speed if two forces in the opposite directions were acting on them. After the instructional interventions, she displayed evidence that she acquired a scientific view about the outcome of balanced forces. When she was asked how an object could move at a constant speed, she showed her scientifically accepted idea that objects could move at a constant speed when the forces acting in opposite direction were equal.

R: What should I do to keep the book moving at a constant speed?
Lisa: You have to take away friction.
R: Take away friction? Ok. What else can I do if I cannot take away friction?
Lisa: Then you apply a force equal to the friction.

In response to further questioning, Lisa showed that she not only knew the outcome of balanced force but she also acquired the scientific view that unbalanced forces caused objects to accelerate.

R: What would happen if one of the forces is greater that the other one?
Lisa: Then the book would move.
R: Move at a constant speed or?
Lisa: It would accelerate.

One idea Lisa possessed before the instructional interventions was her view that objects set in motion acquired a force that kept the object moving. After the instructional interventions, in various situations Lisa displayed evidence for the change in her ideas about the acquired force. For example, when she was asked the forces acting on a book sliding on the table, Lisa did not state any force in the direction of the book's motion.

R: Next question. Suppose that I push this book on the table just like this and it moves from point A to B. Ok. What are the forces acting on this book at A, while it travels from point A to B, and at point B? [Researcher pushed a book and let it slide on the table]
Lisa: At point A it accelerates and your force is exerting on the book. And from A to B the only force acting on the book is friction.
R: Friction.
Lisa: Yeah. At point B. There is no forces acting on the book. Well gravity and normal force. They are acting at all points.
R: What would you say about the speed of the book as it moves from point A to B?
Lisa: The speed is decreasing.
R: Why is it decreasing?

Lisa: Because the friction is accelerating, in this case it is decelerating it.
R: You said that from point A to B the only force acting on the book is friction and additionally gravity and normal force, right?
Lisa: Yeah.
R: At which direction does friction act?
Lisa: It acts in the opposite direction of motion.

Unlike her response in the pre-instructional interview, Lisa stated that there was no need for a force in the direction of the book's motion. Other than gravity and normal force, she thought that the only force acting on the book in the opposite direction of its motion was friction.

In contrast to her response that there was an acquired force acting on a ball moving in the upward direction in the pre-instructional interview, Lisa maintained that the only force acting on the ball throughout its movement was gravity. When she was reminded of her previous idea of acquired force in the direction of ball's upward motion, Lisa stated that she changed her idea of acquired force with inertia.

R: During our first interview you said that as the ball travels up force that you exerted on the ball to throw it up and gravity are acting on the object. Do you still hold this idea?
Lisa: No, I replaced it with the inertia. The ball is continues its path upward but it is decelerating as a result of gravity. The idea of inertia kind of overcame the idea of force of my push.

With the aim of further clarification of her idea of inertia, Lisa was asked whether inertia was an entity that was comparable to gravity.

R: And [in previous interview] you also said that gravity is greater than the force of your push. If you replace the force of your push idea with inertia could you that gravity overcomes inertia or, in other words, gravity is greater than inertia?
Lisa: Well the inertia does not really have any force at all. So they cannot be compared. I mean since it is no force and gravity obviously has acceleration. So it [inertia] is just the fact that the ball is moving in that direction.

As her statements above indicate, Lisa assigned force and inertia into different ontological categories. She not only stated directly that inertia was not a force, but she also maintained that inertia was an entity that was not comparable to a force. It is obvious that Lisa did not consider inertia as an action or process but, rather, for her, inertia was a scientific "fact" that objects continued to move in a direction after they were set in motion. In doing to, Lisa assigned scientifically acceptable attributes to force and inertia.

Previously, Lisa thought that even in the absence of opposing forces there was a need for a force acting on the object to keep it moving at a constant speed. She explained the motion of the object with a force acquired after it was set in motion. Her responses below show how her ideas changed after the instructional interventions.

R: Ok. Suppose that I push this book on a very smooth surface, a frictionless surface. What would happen if I push this book?
Lisa: It will continue. After the force is applied it will continue at a constant speed.
R: Does it stop eventually or does it float around?
Lisa: No it just keeps going until it is acted upon by another force.
R: Why do you think it'll move forever?
Lisa: Because there is nothing stopping it. There is nothing on its way. So it keeps moving.

The excerpt above shows that, for Lisa, there was no longer a need for an acquired force to keep the object moving at a constant speed. Lisa maintained that there was no force acting on the book on a frictionless surface after it was set in motion. She stated that the book would continue to move until another force acted upon it. It is obvious that, for Lisa, the motion of the ball no longer required an explanation. She considered motion as a natural state of objects.

Changes in Lisa's Ideas about Force and One-Dimensional Motion

Throughout the instructional interventions, Lisa changed all of her alternative ideas that were identified prior to the instructional interventions. To sum up the changes in Lisa's ideas, her ideas prior to the instructional interventions and after the instructional interventions are presented in Table 1. A drastic change is seen in her idea that objects acquire force after they are set in motion. Previously, for Lisa, the acquired force in the direction of object's motion kept it moving. After the instructional interventions, she successfully acquired the scientific view of inertia. For her, there was no longer a need for force acting in the direction of object's motion; instead, objects had the tendency to move until a force acted upon them. As Lisa thought that inertia did not have amount and could not be compared with the amount of a force, she displayed evidence that she assigned the inertia concept to a scientifically accepted ontological category. Lisa's association of force with any kind of motion was another idea that she held prior to the instructional interventions. After the instructional interventions, she not only stated that force caused objects to accelerate, but she was also able to differentiate the outcome of

Table 1. Lisa's pre-instructional and post-instructional ideas about force and one-dimensional motion.

Pre-instructional Ideas	Post-instructional Ideas
• Force creates any kinds of motion. • No differentiation of the outcome of balanced and unbalanced forces. • The amount of the force in the direction of the object's motion must be greater than that of the opposing force. • The act of setting objects in motion imparts in them a force. • Force acquired by objects after they are set in motion keeps them moving. Therefore, moving is not considered as a natural state of objects. • Force acquired by an object acts in the direction of object's movement and stays constant throughout object's travel. • Objects cannot move at constant speed if two forces in opposite directions act on the object.	• Force is a push or a pull. • Force causes objects to accelerate. • Unbalanced forces cause objects to accelerate. • Balanced forces cause objects to move at a constant speed. • There is no need for net forces in the direction of an object's motion. An object may move at a constant speed when the net force acting on it is zero. • There is no need for a force that keeps objects moving. Objects can move at a constant speed without force acting on them. • Natural state of objects can be motion. Objects keep moving until a force is acting on them. • Inertia is not a force. It does not have amount and cannot be compared with the amount of a force.

balanced and unbalanced forces. She previously thought that objects could not move at a constant speed when two forces in opposite directions acted upon them. After the instruction, Lisa was able to successfully grasp the scientific understanding that balanced forces caused objects to move at constant speed, and unbalanced forces caused objects to accelerate. As Lisa learned the outcome of balanced and unbalanced forces, she accepted the scientific view that there was no need for net forces in the direction of an object's constant motion.

The data from the pre- and post-instructional interviews indicate that Lisa acquired a better scientific understanding after the instructional interventions. She changed all of her alternative ideas that were identified prior to the instructional interventions with scientific views of force and motion. Her acquisition of a better scientific understanding of force and motion concepts after the instructional interventions is also seen in her scores on the pre- and post-FCI. Although Lisa could only answer 8 items of the FCI correctly before the instructional interventions, she responded correctly to the 27 items of the FCI after the instructional interventions.

Overview of the Types of Metaconceptual Processes

To better understand the metaconceptual processes that Lisa engaged in, it is necessary to provide a brief description of the qualitatively different metaconceptual processes derived from the analysis of the transcripts. There are three main types of metaconceptual processes found in the data: (a) metaconceptual awareness, (b) metaconceptual monitoring, and (c) metaconceptual evaluation. During the data analysis, after assigning the student's statements to these general types of metaconceptual processes, subcategories were developed by comparing one incident to another. The data was gone over for several times to find segments that exemplified the list of metaconceptual processes in the coding scheme. Below is the description of the general types of metaconceptual processes and subcategories appeared in each one of them.

Metaconceptual Awareness

Metaconceptual awareness is a process in which the learner explicitly refers to her/his personal stock of information including current or past ideas regarding a concept, presuppositions, experiences, and contextual differences. Two categories of metaconceptual awareness were found in the data: first-order awareness and second-order metaconceptual awareness.

A. *First-Order Awareness:* First-order awareness is one's explicit recognition of or reflection on existing concepts, generative or stored representations of the physical world, and elements of conceptual ecology. As learners engage in first-order awareness, they may also refer to a conceptual entity that is missing in their existing conceptual structure. Within the category of first-order awareness, five subcategories were derived from the data.

1) *First-Order Awareness of Mental Models and Ideas/Conceptions:* Learners are considered to be metaconceptually aware of their ideas or mental models when they make explicit reference to their existing or generative ideas through talking, writing, or creating drawings about ideas.

2) *First-Order Awareness of Ontological Presuppositions:* Learners are assumed to be metaconceptually aware of their ontological presuppositions when they explicitly reflect on their ontological beliefs about how and in what form entities exist in the world, or the properties that entities may possess as a result of belonging to an ontologically distinct category.
3) *First-Order Awareness of What You Do Not Know: One's* realization that a conceptual variable is missing in his/her current explanation or one's recognition that she/he does not know how that variable works in the given situation is a process characterized by this subcategory
4) *First-Order Awareness of Contextual Differences:* Learners are assumed to become aware of the contextual differences when they explicitly make reference to contextual factors as they provide explanations for a physical phenomenon. Contextual factors may involve the variables about the characteristics of the environment (frictionless surface vs. surface with friction), or situated variables (object moving as a result of unbalanced forces vs. object moving as a result of balanced forces).
5) *First-Order Awareness of Experiences:* Learners make reference to a particular experience when they engage in first-order awareness of past experiences.

B. *Second-Order Metaconceptual Awareness:* It is a process in which the learners explicitly refer to their previous science concepts or other elements of their conceptual ecology that they had in the past. The same subcategories of first-order awareness apply to second-order metaconceptual awareness.

1) *Second-Order Metaconceptual Awareness of Initial Ideas/ Mental Models:* Learners engage in second-order metaconceptual awareness of initial ideas or mental models when they talk about ideas they held at an earlier time.
2) *Second-Order Metaconceptual Awareness of What You Did Not Know:* In addition to awareness of ideas they held at an earlier time, learners may also have knowledge about what they did not know in the past, what variables were missing in their previous conceptual structure, or how a conceptual variable works in a situation.
3) *Second-Order Metaconceptual Awareness of Contextual Differences:* Second-order metaconceptual awareness of contextual differences is a process in which the learner reflects on her or his past use of concepts in different contexts.
4) *Second-Order Metaconceptual Awareness of Ontological Presuppositions:* Learners engage in second-order metaconceptual awareness of ontological beliefs when they refer to their previous ontological presupposition about the kinds of entities and the way they are categorized.
5) *Second-Order Awareness of Experiences:* Second-order awareness is a process in which learners think about how they interpreted their experiences in the past.

Metaconceptual Monitoring

Metaconceptual monitoring processes are "online" and "in the moment" processes that generate information about an ongoing cognitive activity, thinking process, or one's present cognitive state in relation to a new information. Metaconceptual monitoring entails controlling of one's cognitive state when she or he comes across with a new conception. Five types of metaconceptual monitoring processes were found in the data.

1) *Monitoring of Understanding of an Idea:* Monitoring one's understanding of an idea is a process in which learners comment on their comprehension of an idea.
2) *Monitoring Ideas/Information from Other People/Sources:* Monitoring other people's ideas is a process in which learners make reference to the content of other people's ideas or information coming from other sources.
3) *Monitoring the Consistency Between New Idea and Existing Idea:* Learners engage in this *process* when they make comparisons between what they already know or think and the information that comes from other sources such as other students, books, or a teacher.
4) *Monitoring the Consistency between Existing Idea and New Experience:* Learners who engage in this *process* compare their own ideas with what they observe or experience.
5) *Monitoring Change in Ideas:* Monitoring the change in one's ideas is a process in which the *learner* makes a comparison between what she or he initially knew and what her or his current ideas are.

Metaconceptual Evaluation

In an attempt to learn a new conception, learners evaluate conceptions by making judgmental decisions about their existing ideas or new conceptions. Learners may engage in this evaluation process in different forms. Although the ways learner engage in metaconceptual evaluation may be different, the end product is an evaluation of the ability of competing conception to explain the physical phenomenon. Learners may metaconceptually evaluate concepts by:

1) making comments about the relative plausibility and usefulness of existing or new ideas. In doing so, learners may directly explain why an idea is attractive or believable to them. Learners may not always use terminology to talk about the plausibility of their ideas. They may also simply refer to the plausibility of an idea by stating the reason for why an idea is wrong and another is true. These processes require the learner to make comment "about" an idea.
2) choosing an idea among different alternatives and defending why that idea works better than the other ones for the given situation.

Lisa's Metaconceptual Processes about Force and One-Dimensional Motion

The aim of this section is to describe Lisa's metaconceptual processes related to force and one-dimensional motion. As Lisa participated in various metaconceptual teaching activities, she engaged in several types of metaconceptual processes. Having force and one-dimensional motion as the main content area, her metaconceptual processes are described within three conceptual subtopics: definition of force, Newton's First Law and relative amount of forces to move an object. Within each conceptual topic, students' metaconceptual processes are described in a chronological order to give a sense how their ideas evolved as they engaged in those processes.

Lisa's Metaconceptual Processes about the Definition of Force. Prior to the instructional interventions, Lisa was not able to identify acceleration as the outcome of force, but rather she associated force with any kinds of motion. Throughout the instructional activities, Lisa became aware of this idea as she attempted to define force concept and identify the relationship between force and the movement of objects.

During the poster drawing activity, Lisa became aware of her understanding of force. The excerpt below is taken from poster drawing activity.

Brandon:	Alright, David, force.
David:	Yeah, force.
Brandon:	What do you think Kevin?
Lisa:	Like energy being applied to an object.
David:	Well, Yeah. So what you can see is like a symbolic force.
Brandon:	Energy applied to an object in a direction or not?
Lisa:	Yeah, in the direction.
David:	Direction.
Brandon:	Energy applied to an object in a direction. Write that down. (Excerpt from poster drawing activity, activity 1)

As the excerpt above shows, Lisa engaged in first-order awareness of her ideas about force by making an explicit definition of it. She defined force as energy applied to an object. In doing so, she associated force with energy, which is an entity that can be transferred from one object to another. During the same activity, Lisa explicitly showed that she did not only associate force with energy, but also with motion.

Lisa:	Okay, attributes used to describeforce.
David:	Intangible. It's not something you can hold in your hand necessarily.
Lisa:	Motion.
Brandon:	Motion.
David:	Motion, magnitude. (Excerpt from poster drawing activity, activity1)

In her attempt to list the attributes of force, Lisa explicitly identified motion as an attribute of force. In doing so, she revealed her idea regarding her association of force with motion rather than acceleration (first-order awareness of her idea). During the class discussion, which took place after group discussion about a book moving as it was constantly pushed by the teacher's finger from point A to B, Lisa explicitly restated her idea that force caused objects to move. Below is the excerpt taken from the class discussion (T denotes Teacher).

T:	Is there any relationship between the forces acting on the object on its way from point A to B? Is there any relationship between the forces acting on the object and its motion?
Lisa:	Yes.
T:	What would they be? So what relationships are there between forces and motion?
Lisa:	Forces create motion. (Excerpt from class discussion after activity 2)

When the teacher asked students whether there were any relationships between forces acting on objects and their motion, Lisa did not distinguish acceleration as the outcome of force from other kinds of motion but, rather, she made an explicit reference to her idea that "forces create motion" (first-order awareness of her idea).

At the end of the instructional activities, when students were given their initial posters to make change in the ideas presented in the poster, Lisa displayed evidence for her ability to become aware of her current understanding of force and monitoring changes in her ideas regarding the definition of force. The excerpt below is taken from students' dialogue prompted by poster revisiting activity.

David:	Our original definition was energy applied in a direction to an object. We should change it to…
Lisa:	Definition of force…

David: Interaction in a direction?
Lisa: Yeah, interaction that can cause acceleration.
David: Or change in the state of motion.
Kevin: Interaction between objects that can cause a change in the objects' current state of motion.
Lisa: Okay. We change energy to interaction that can…
[students chose markers to make changes in their original poster]
David: Okay. We change energy to interaction okay not that causes but that can cause a change in the objects' current state of motion. (Excerpt from poster revisiting activity, activity 12)

As the above excerpt indicates, at the end of the instructional interventions, Lisa no longer associated force with any kinds of motion but, rather she was able to differentiae acceleration as the outcome of force from other kinds of motion ("Yeah, interaction that can cause acceleration."). She was not only aware of her current definition of force, but she also displayed evidence for her ability to monitor changes in her initial definition of force ("Okay. We change energy to interaction that can…").

Lisa's Metaconceptual Processes about the Relative Amount of Forces Needed to Move an Object. The aim of this section is to describe Lisa's metaconceptual processes regarding her ideas about the amount of forces needed to keep objects moving. Before the instructional interventions began, Lisa could not differentiate the outcome of balanced and unbalanced forces. She believed that the force in the direction of the object's motion had to be greater than the force acting in the opposite direction, even if the object was moving at a constant speed. Lisa displayed evidence for her engagement in first-order awareness of this idea in a journal entry related to activity 2. In activity 2, students were asked to push a book on the table by exerting a constant push. Before group discussion, students were asked to make a journal entry that explained the forces acting on the book. Below is Lisa's journal entry written in response to questions provided in activity 2.

> [The forces acting on the book are:] The push [force from hand], friction, air forces, gravity.
> [Direction of the forces:] Push: forward, friction: backward.
> The [amount of the] push is constant overcoming friction.
> It [motion of the book] is constant because push is constant and so is friction. (Journal entry before group discussion in response to activity 2)

In the above excerpt, Lisa described her ideas regarding the type, direction, and amount of forces. Although she claimed that the book was moving at a constant speed ("It [motion of the book] is constant…"), she explicitly stated that the force exerted in the direction of the book's motion was greater than friction ("The [amount of the] push is constant overcoming friction.") (First-order awareness of her idea). Also for Lisa, the book moved at a constant speed because constant forces were acting on it ("It [motion of the book] is constant because push is constant and so is friction.") (first-order awareness of her idea). She attributed the steadiness of the book's speed to the constant forces rather than the equality of forces acting on the book.

After group and class discussion regarding activity 2, when students were asked to write journals, Lisa displayed evidence for another type of metaconceptual awareness. In journal prompt, students were asked to write about situations in which their ideas did not work and whether they found any attractive ideas during group and class discussions. Below is an extract taken from Lisa's journal entry.

> Situations where there is no friction will not have the same results as this experiment. Also, situations where there is no gravity will result in different observations…. Since I agreed with most things I wasn't attracted to different ideas. I don't see my limitations of these ideas but I wouldn't be surprised if there are some. These situations are the only one I can think of. (Journal entry written in response to journal prompt 2 given after activity 2)

In the above extract of Lisa's journal entry, she displayed her ability to become aware of a context in which exertion of a constant force on the object would result in differences in the motion of the object. On a surface with friction, she thought that the object moved at a constant speed because of the constant forces (see evidence for this idea of Lisa in her previous journal entry). She recognized that on a frictionless surface exertion of a constant force on the object would cause a different type of motion other than constant movement. ("Situations where there is no friction will not have the same results as this experiment."). In doing so, Lisa engaged in first-order awareness of contextual differences between the motion of objects on frictionless surface and on a surface with friction. Although she recognized that the motion of the object would be different on a frictionless surface when a constant force acted on it, she did not display any evidence for noticing that her idea (constant force caused an object move at constant speed) was not applicable to the situations she was aware of.

Lisa claimed that she neither recognized "attractive" ideas nor found any limitation of her own ideas during the group or class discussions ("…I wasn't attracted to different ideas. I don't see my limitations of these ideas…"). It is clear that, for Lisa, her own ideas about the forces acting on the book were still plausible to her. She engaged in metaconceptual evaluation in the form of reflecting on the plausibility of her own ideas. Lisa's engagement in metaconceptual evaluation was limited to reflecting on the status of her own idea. She neither compared the status of her idea with another competing idea nor provided any justifications for her idea. In that sense her metaconceptual evaluation process was not sophisticated.

When students were asked to make a journal entry in which they group similar situations (different situations were provided in a table along with a journal prompt) and examine the consistency of their initial and current ideas for different situations, Lisa engaged in a more sophisticated metaconceptual process. Below is an extract taken from her journal entry.

> Another division is constant or increasing velocity. Before I treated them the same, I thought you had to have unbalanced forces for constant speed and acceleration. But now I know the difference, i.e., balanced forces or no forces cause constant velocity and unbalanced forces cause acceleration or deceleration. (Excerpt from journal entry written in response to journal prompt 11).

In the excerpt above Lisa showed evidence for her engagement in an impressive multifaceted metaconceptual process about her ideas regarding balanced and unbalanced forces. She grouped her initial and current ideas in terms of the type of objects' motion, constant motion, and acceleration ("Another division is constant or increasing velocity."). She was not only aware of her initial ideas about the amount of forces needed for objects' motion, but she was also able to compare her initial ideas across the situations where objects were moving at a constant speed and increasing speed ("Another division is constant or increasing velocity. Before I treated them the same, I thought you had to have unbalanced forces for constant speed and acceleration."). She recognized that she held the same idea for situations where the object was moving at a constant speed and at increasing speed. It is clear that she compared her initial ideas across different contexts (object moving at constant speed vs. increasing speed). In doing so, she engaged in second-order awareness of contextual differences.

Lisa was not only aware of her initial ideas, but she also displayed evidence for her engagement in monitoring changes in ideas regarding the outcome of balanced and unbalanced forces. She was able to compare her initial ideas with her current ideas. ("… I thought you had to have unbalanced forces for constant speed and acceleration. But now I know the difference, i.e., balanced forces or no forces cause constant velocity and unbalanced forces cause acceleration or deceleration.").

Lisa's Metaconceptual *Processes about Newton's First Law.* Prior to the instructional interventions, Lisa believed that objects acquired a force after they were set in motion. For her, the acquired force acting in the direction of the motion kept the object moving. Throughout several instructional activities, Lisa engaged in various types of metaconceptual processes related to her idea of acquired force.

Lisa made explicit reference to her idea about the acquired force in the direction of object's motion in the journal written before a group discussion activity. In this activity, students were requested to identify forces acting on a moving book after it was set in motion by a strong push. Below is the excerpt taken from Lisa's journal entry?

> Force of the push, friction, air forces and gravity.
> The force of the push is a force stronger than friction. Later as the book slows, friction is stronger.
> The push is forward, the friction is backward, air forces are all around and gravity is downward.
> The item slows down, decreasing in speed.
> The motion is slowed by friction while the force of the push continues to have the book move forward until friction takes over and the book rests. (Journal entry written in response to the B part of activity 2)

In the above excerpt, Lisa explicitly articulated her idea that the force applied to push the book on the table was still acting on it until it became at rest. In this journal entry, her metaconceptual process did not go beyond first-order awareness of her existing ideas. ("The motion is slowed by friction while the force of the push continues to have the book move forward until friction takes over and the book rests."). It is clear that, for her, force applied to push the book transferred from the hand to the book and became an internal property of the book.

In a journal entry, which Lisa wrote before group debate prompted by activity 3, she made explicit reference to her ontological presuppositions about force and objects' natural state of being. In activity 3, students were asked to choose between two alternatives about forces acting on an object moving on a frictionless surface. Students were requested to defend one idea against the other. Lisa chose alternative B, which involved the idea that there was a force acting on the object in the direction of its motion on frictionless surface. Below is Lisa's journal entry written prior to group debate?

> I think there is force acting on the object in the direction of its motion. Reasons:
> If it collides its force will be transferred, therefore it must still have force when it collides.
> The object is still moving. An object will not move without force.
> The motion of the object would be horizontal. On a frictionless surface the object will be slowed down. The forces are the same except for friction. The reason for this is that only one variable has been changed. Other forces are controlled. (Journal entry written in response to activity 3)

For Lisa, there was force acting in the direction of object's motion as it moved on frictionless surface. Lisa did not only make reference to this idea, but she also engaged in metaconceptual evaluation as she provided justifications for her idea. As she defended her idea, she justified her idea by making reference to her experiences and ontological presuppositions about force and natural state of objects. Lisa recognized her ontological presupposition that objects could not move without force acting on them. For her, motion was not a natural state of objects ("The object is still moving. An object will not move without force"). Lisa also became aware of her ontological presupposition about the nature of forces. She referred to an experience in which a moving object struck another object that was at rest, and after the collision, the moving object stopped and the object at rest started moving. ("If it collides, its force will be transferred therefore it must still have force when it collides."). Since, for her, the object could not move without a force acting on it, force from the moving object had to be transferred to the object at rest to start its movement. It is obvious that in an attempt to justify her idea, Lisa became aware of her ontological presupposition that force was an entity that was transferred from one object to another (first-order awareness of ontological presupposition).

During the group debate prompted by activity 3, Lisa displayed evidence for her engagement in other types of metaconceptual process, such as monitoring ideas of other people, metaconceptual evaluation in the form of making reference to the plausibility of an idea, and first-order awareness of what she does not know. Below is an extract taken from students' dialogues, which took place during group debate.

Lisa: Are you A or B?
David: I'm A.
Connor: I'm A. No, wait, I'm B. I'm B. Can I go first? I said that there's horizontal force acting upon the object. I think that the hand, you still exert force over the object even though you're not still physically touching it. It's moving because of the initial force that you applied. That was my answer.
David: This is David and I am A. This just makes more sense. I think that the force acting is gone after your hand leaves the object. It's still moving. Friction slows it down. If there were friction the object would slow down. If there is no friction there is nothing to slow it down. It wouldn't have to counteract any kind of force. It's like a hockey puck it just moves in a direction. It doesn't counter anything.
Lisa: You're saying that after the push there is no force acting upon it?
David: There's this momentum, but if it was on a certain friction it wouldn't move. It would slow down because of friction. It almost keeps going because of the lack of friction.
Connor: I cannot follow what you said. What do you think about when something collides?
David: See that's the part that I'm not sure about. Because I mean it might depend on the mass of the objects that collide, or the weight, or what. If there is friction and if you just pushed it, it would eventually slow down and stop because friction acts upon it. Up to now we've just defined constant forces produces constant speed. But on a frictionless surface if you push it, it keeps going. There is nothing to slow it down.
Connor: But, you know, the initial force from your hand and like if friction is slowing it down the force from your hand is going to ...
Lisa: Yeah, the friction is overcoming the force from your hand more and more. But I did see the point of lack of force. That makes sense too. It's really not intelligent if you don't have enough information. I'm really interested in that conversation. It's hard. We can't really back it up.
David: Yeah, because we haven't done any kind of I mean ... Well, I've been trying to think of an example. But if a hockey puck, if it's just running across the rink, whether or not it has any hand pushing it across the rink, it keeps going. Yeah, if it runs into a marble, it's still gonna push the marble, but if it runs into the wall of the rink, it's not going to do anything. But it still has that momentum
Lisa: Yeah, is momentum a force?
David: I don't know, but it's what we've been debating.

Lisa: Yeah, what's the definition of force?
David: Yeah, we don't even know what the definition of force is, so we can't really say whether the momentum is a force or not
Connor: I think the momentum is where you ram your hand back and then shove it.
David Yeah, I'm just trying to decide what exactly is momentum? But if it is moving is that a force or momentum?
Lisa: Yeah, momentum is kind of like the aftershock of force. But you don't know if it is force.
David: Right, exactly. I suppose this whole thing depends on the fact that none of us really know what force is. But I don't really know what it [momentum] is, but I think it is there.
Lisa Yeah, it's just a guess. (Excerpt from group debate in response to activity 3)

In the excerpt above, Lisa revealed her idea that on a surface with friction, force acquired from the hand was overcame by friction as the object slowed down ("Yeah, the friction is overcoming the force from your hand more and more.") (first-order awareness of her idea). Lisa also displayed evidence for her ability to monitor David's idea that no force was acting on the object as it moved ("But I did see the point of lack of force."). Lisa reflected on the plausibility of David's idea by saying that it made sense for her ("That makes sense too.") (metaconceptual evaluation). However, Lisa did not provide any reasons or justifications for why she found David's idea plausible. Throughout the discussion, although David engaged in metaconceptual evaluation by providing justifications for the idea he chose based on his experiences and knowledge about the motion of objects on frictionless surface, Lisa's engagement in metaconceptual evaluation could not go beyond commenting on the plausibility of David's idea. Lisa recognized that she did not have adequate knowledge to metaconceptually evaluate one idea against the other ("It's really not intelligent if you don't have enough information. I'm really interested in that conversation. It's hard. We can't really back it up."). In doing so, she engaged in first-order awareness of what she did not know. Her realization of not possessing adequate information made her pay attention to the content of their discussion. Later in the conversation, Lisa recognized that she did not know the definition of momentum and force ("Yeah, is momentum a force? … Yeah, what's the definition of force?") (first-order awareness of what she does not know). Although Lisa defined momentum as an "aftershock force," she did not know whether it is considered as a force or not ("Yeah, momentum is kind of like the aftershock of force. But you don't know if it is force.").

After group debate, students wrote in their journals about the ideas they discussed during group debate and class discussion. In a journal entry written in response to journal prompt 3, Lisa stated that she did not change her ideas after group and class discussions. Lisa's journal entry is below.

> I understood what my partner was mostly saying. I did not understand his explanation of how a colliding object proves his stance. He does not believe that a force is acting on it because the hand is gone. I have faith that there is something that keeps the object moving (force). To argue intelligently we need to know what the definition of force is. I didn't change my mind because I feel my point has more proof behind it then my partners point had. (Journal entry written in response to journal prompt 3, after activity 3)

The excerpt above shows that Lisa successfully monitored David's idea that there was no force acting on the object as it moved on a frictionless surface ("He does not believe that a force is acting on it because the hand is gone."). She also monitored her understanding of David's idea. Although Lisa understood the content of David's idea, she did not understand how David's idea explained the forces acting on colliding objects ("I did not understand his explanation of how a colliding object proves his stance."). Lisa not only engaged in monitoring changes in her ideas, but she also metaconceptual evaluated her own idea against David's idea. For her, her own idea was more plausible than David's idea because her idea about the force transfer during the collision of objects served as a proof for the validity of her idea ("I have faith that there is something that keeps the object moving (force). …I didn't change my mind because I feel my point has more proof behind it then my partners point had"). In other words, although she found David's idea intelligible, the same idea was not plausible to her due to the inability of David's idea to explain the motion of colliding objects. At the time she made the above journal entry, she did not change her idea that force acquired from the agent kept the object moving.

After the tasks related to activity 3 were completed, the teacher introduced Newton's First Law of inertia. In the journal entry written in response to journal prompt 4, Lisa displayed evidence that she changed her idea of acquired force with the scientifically accepted view of inertia.

> Yes, I understand that objects in motion remain in motion. I know this because I can use examples to support my thoughts. I believe everything.
> The difference in understanding is all a "word-game." I agree with everything in my thoughts. The words I used to express my ideas were

defined differently than how I used them. The way Newton's Law and the definition of words [inertia] put my views into a clearer nature. It makes my ideas look nicer, neater, and is easier to work with.

The one idea that changed was really an adjustment. I said a force is motion and therefore an object after being pushed still has my definition of force. If you define force as an interaction my statement is wrong. It's all a word game. What I thought of as included in my definition of force, Newton called inertia. Newton's definitions and laws better explain motion. It divides my definition of force into different groups based on what happens to the objects.

My [current] definition includes:

Inertia: a constant velocity

Force: an acceleration (unbalanced)

I didn't define what these two ideas individually did. (Journal entry written in response to journal prompt 4)

In the above journal entry, Lisa used sophisticated metaconceptual processes, such as monitoring her understanding of ideas, second-order awareness of what she did not know before, monitoring changes in her ideas and metaconceptual evaluation. She was able to successfully monitor her understanding of Newton's First Law of Inertia. Her statement of the law was consistent with the scientific view ("Yes, I understand that objects in motion remain in motion."). For her, using examples was a way to check her understanding of the law ("I know this because I can use examples to support my thoughts.").

In the above excerpt, Lisa engaged in a very impressive metaconceptual process in the form of monitoring of changes in her ideas. For Lisa, the changes in her ideas were a "word-game." She was aware that she initially used the word "force" to define her idea of objects' motion that they have after being exerted by a force ("I said a force is motion and therefore an object after being pushed still has my definition of force"). In doing so, she engaged in second-order metaconceptual awareness of her initial ideas. Lisa was able to monitor that her initial idea of force (acquired force) was defined differently by scientists ("The words I used to express my ideas were defined differently than how I used them."). She was aware that she considered inertia as a force. She monitored the consistency of her initial idea with the Newtonian view of inertia as she stated that her idea of acquired force was defined as inertia by Newton. ("It's all a word game. What I thought of as included in my definition of force, Newton called inertia.").

Lisa was also able to make reference to her current understanding of force and inertia. She differentiated the outcome of inertia and force. She acquired the scientific view that objects moved at a constant speed due to their inertia, and they accelerated as a result of unbalanced forces. Lisa realized that she could not make this differentiation before ("I didn't define what these two ideas individually did.").

Lisa also engaged in metaconceptual evaluation as she made an epistemological comparison between her previous ideas and Newton's Laws. For Lisa, the ideas presented in Newton's Laws were clearer and easier to use ("The way Newton's Law and the definition of words [inertia] put my views into a clearer nature. It makes my ideas look nicer, neater, and is easier to work with."). Another criterion that served as a basis for metaconceptual evaluation was the ability of Newton's Laws to distinguish fundamental concepts such as inertia and force based on the type of motion of the objects. For Lisa, while her previous understanding of force could not differentiate constant speed and acceleration as the outcome of force, Newton's Laws stated that the objects accelerated because of forces being acted upon them and they continued to move at a constant speed due their inertia ("Newton's definitions and laws better explain motion. It divides my definition of force into different groups based on what happens to the objects.").

Lisa's ability to recognize the ontological distinction between inertia and force was also seen in her journal entries related to activity 7. In activity 7, students were asked to choose one of six pictorial representations that depicted the forces acting on a ball tossed up as it was rising. Having acquired the scientific view of inertia, in her pre journal entry, Lisa identified gravity as the only force acting on the ball throughout its travel ("Gravity is the only force acting on the ball."). In the same journal entry Lisa made reference to the ontological distinction between inertia and force ("Inertia is a property, tendency to maintain its current motion. Force: interaction and ability to accelerate."). Lisa was able to refer to the ontological characteristics of force and inertia. While Lisa considered inertia as a property of objects, she defined force as an interaction. In doing so, Lisa engaged in first-order awareness of her ontological presuppositions. Lisa was able to make a similar distinction in her journal entry written in response to journal prompt given after activity 7. She explicitly stated that she did not consider inertia as a force and in the force diagram only gravity had to be shown ("No force is acting upward. Inertia is not a force. Gravity is the only force acting on the ball. … In a force diagram only gravity should be shown").

Lisa's ability to monitor changes in her ideas about Newton's First Law of Inertia was seen in one of her journal entry.

The main difference in my initial and current ideas is the idea that inertia is a force. I said that

> there was a force if the object was moving even the applied force was long gone. (Excerpt from journal entry written in response to journal prompt 11)

Lisa was capable of monitoring that she changed her initial idea of acquired force with the concept of inertia. She was aware that her initial definition of acquired force was scientifically defined as inertia. As she monitored the changes in her idea, she made reference to her initial idea about acquired force ("I said that there was a force if the object was moving even the applied force was long gone.").

Summary of Lisa's Metaconceptual Processes about Force and One-Dimensional Motion

Throughout the instructional activities related to force and one-dimensional motion, Lisa displayed evidence for her engagement in various types of metaconceptual processes. At various points during journal writing, group and class discussions, Lisa become aware of her current and previous ideas. She was able to make explicit reference to many of her existing ideas identified prior to the instructional interventions. The excerpts show Lisa's engagement in the first-order awareness of the following alternative ideas: (a) force is energy applied to an object in a direction, (b) forces create motion, (c) force in the direction of object's constant motion is greater than the force acting in the opposite direction, (d) objects move at constant speed because constant forces are acting on them, (e) the force acquired from the agent still acts on the object even though the object lost its contact with the agent, (f) the acquired force acting in the direction of the object's motion keeps the object moving.

Lisa became aware of her experiences and ontological presuppositions either to provide explanation for a situation or to justify competing ideas as she evaluated them. For example, as Lisa defended her idea, she became aware of her ontological presuppositions regarding the natural state of objects and nature of force. For Lisa, objects' motion needed explanation. She made reference to her ontological presupposition that objects could not move without force acting on them. She was also aware that she considered force as an entity that could be transferred from one object to another. After she acquired a scientific understanding of inertia, she was able to explicitly distinguish the ontological characteristics of inertia and force. She was aware that she considered inertia as a property and force as an interaction.

In addition to her first-order awareness of her ontological presuppositions, Lisa displayed evidence for her ability to make reference to contextual differences. She recognized that the motion of objects on a frictionless surface would be different from their motion on a surface with friction. Lisa's ability to become aware of the contextual difference went beyond first-order level of awareness. She was able to compare her use of initial ideas in two contexts, where objects were moving at a constant speed and at increasing speed. She was aware that she held the same idea (force in the direction of the object's motion had to be greater than the force in the opposite direction) for both situations.

Lisa's engagement in second-order awareness was seen when she made reference to her idea regarding the acquired force. She recognized her initial belief that the force applied by an agent was still acting on the object as it moved even though the object was no longer in touch in the agent. Her awareness of her initial ideas was also seen when her group revisited their poster drawn at the beginning of the instructional interventions. She recognized that she initially defined force as energy applied in a direction.

As Lisa participated in the instructional activities, she became aware of the conceptual entities that she did not know. For example, while she defended her idea about whether force was acting on an object on a frictionless surface, she realized that she did not know the definition of force and momentum. Her realization of what she did not know caused her to pay attention to the content of the discussion. Her awareness of what she did not know was not limited to first-order level of awareness. After she acquired a scientific view about inertia, she realized that she did not know the difference between the types object's motion resulted from unbalanced forces and inertia (objects continue to move at a constant speed due to their inertia and they accelerate as a result of unbalanced forces acting on them).

Throughout the group discussions, Lisa was not only aware of her own idea, but she displayed evidence that she could monitor her group mate's ideas. For example, she could correctly restate David's idea that there was no need for a force to keep objects moving. She was also able to monitor the inconsistency between her idea of acquired force with Newtonian view of inertia.

Another type of metaconceptual monitoring process that Lisa was able to engage in was her monitoring of her understanding of ideas. For example, she claimed that she understood Newton's First Law. Her statement of Newton's First Law in her own word shows that she acquired a scientific understanding of the inertia concept. For Lisa, one way of checking her understanding was using her idea in different examples.

Lisa's ability to monitor the changes in her ideas was seen in different conceptual topics. For example, she recognized that she initially did not differentiate the amount of forces acting on objects that were accelerating and moving at a constant speed. Lisa displayed evidence for monitoring changes in her ideas when she made reference to her current idea that unbalanced forces caused objects to accelerate, and balanced forces caused objects to move at a constant speed. Lisa was also able to monitor the change in her initial idea of acquired force with inertia. For her, the change in her initial idea of acquired force with inertia was a "word-game." She was aware that her previous idea of acquired force was defined as inertia by scientists. Being aware of the change in her initial idea of acquired force with inertia and being able to differentiate the ontological characteristics of force and inertia, Lisa showed that she monitored the ontological shift in her ideas when she made an ontological distinction between force and inertia (force is interaction, inertia is a property).

Metaconceptual evaluation was another qualitatively different metaconceptual process for which Lisa displayed evidence. At various points during group discussions and in her journal entries, Lisa reflected on the plausibility of her ideas and ideas of other students, and she commented on the relative usefulness of Newton's Laws compared to her own ideas. For example, in a journal entry about forces acting on an object moving at a constant speed as a result of being pushed by hand, she maintained that she neither found any attractive ideas nor saw any limitations of her own idea during group and class discussions. Her statements indicated that her ideas were still plausible to her. At another point, Lisa maintained that she retained her existing idea about the need for forces to keep objects moving on a frictionless surface. She explained her reasoning behind her idea with an example about colliding objects. For her, a stationary object started to move as a result of a collision with a moving object due to the transfer of force from the moving object to stationary object. As she maintained that David's idea (no force is necessary to keep objects moving) could not explain the motion of colliding objects and her idea had more proof, she engaged in metaconceptual evaluation in the form of making comparative judgmental decisions about her own idea and David's idea. Lisa also engaged in less sophisticated form of metaconceptual evaluation, as she commented on the plausibility of an idea without providing any reasons or justifications. While Lisa defended one idea against another, she realized that she did not posses enough information to make a correct judgmental decision about ideas. For example, she realized that she needed to know the definition of force to argue about ideas. Lisa was also able to make an epistemological comparison between her initial idea of acquired force and Newton's Laws. For Lisa, Newton's Laws are clearer and easier to work with than her own ideas. Compared to her initial idea of acquired force, for Lisa, Newton's definition of force and inertia could distinguish the types of motion (constant speed due to inertia vs. acceleration due to unbalanced forces), while her initial understanding of force could not make such as a differentiation.

DISCUSSION, CONCLUSION and IMPLICATIONS

In this paper, one student's science ideas that she had prior to and after the metaconceptual teaching interventions were examined and the changes in her ideas were summarized. Then, her metaconceptual processes about those ideas were portrayed. In describing the student's metaconceptual processes, they were examined by using taxonomy of metaconceptual processes derived from the analysis of the collected data. The findings of the study indicate that all of the student's alternative ideas identified prior to the instruction changed with the scientifically accepted conceptions following the metaconceptual teaching practices. The findings also showed that this student engaged in several types of metaconceptual processes ranging from simple awareness of her ideas to more sophisticated metaconceptual processes, such as monitoring and evaluation of ideas.

The findings of this exploratory case study should be interpreted carefully. Although the observed changes in the student's science ideas and the relevant metaconceptual processes strengthens the claims about the positive role of metaconceptual processes in learning science conceptions, a one-to-one causal relationship between particular types of metaconceptual processes and the change in particular ideas could not be drawn from the collected data due to the multifaceted and multidimensional character of metaconceptual processes. To date, the nature of the mechanisms of this relationship has not been fully identified. An isolation of a single type of metaconceptual process and investigating the effect of that process on the changes in science ideas would not be possible as some processes already involves one's engagement in other metaconceptual processes or a single metaconceptual process may invoke one's engagement in others. For example, monitoring changes in ideas requires a learner to engage in first-order awareness of current ideas and second-order awareness of initial ideas and make a comparison between initial and current ideas.

Any theoretical and/or empirical attempt to investigate the nature and mechanisms of how a particular type of metaconceptual process influences and brings about change in students' ideas would be a great addition to our understanding of concept learning. It is clear that both conceptual change and metaconceptual processes are complex and occur through the interaction of several constructs. In this study, the observed changes in the student's ideas should not be treated as the single cause of the observed metaconceptual processes but rather they are the product of the interaction of metaconceptual and cognitive processes as well as social and motivational factors. Therefore, the observed metaconceptual processes should be considered as a contributor to the restructuring in the participant's conceptual system.

Keeping in mind that making an attempt to show a particular type of metaconceptual process as the cause of the changes in students' ideas can be only partially successful; it would not be inappropriate to state that the participant of this case study became aware her existing alternative ideas, mental models and relevant ontological presuppositions, consciously compared and contrasted existing ideas with information coming from different sources, monitored the changes in her ideas and evaluated the validity of ideas by providing justifications. The findings indicate that this student who engaged in these domain specific metaconceptual processes was able to realize the limitations of her idea, construct new ones that were more plausible and fruitful to her and recognize the phenomenon that she did not know or understand. Her realization of the missing elements of her conceptual ecology enhanced her interest to understand the unknown conceptual entities. It is obvious that all of these processes have potential to contribute to the acquisition of conceptions that were accepted with the science community. Examination of the participant's responses to interview questions provides an evidence for the extent of the changes in her ideas of force and one-dimensional motion. Her responses indicate that the changes in her ideas not only were at the factual level but her ideas also changed at the ontological level implying not a surface level but a major restructuring in her conceptual structure about force and motion. It would not be inappropriate to claim that the ontological changes in her ideas should be closely related to her metaconceptual awareness of the ontological distinctions between inertia and force concept which was activated through metaconceptual teaching interventions. Wiser and Amin's study (2001) also reported the positive effect of metaconceptual teaching that addresses the fact that students and scientists may use the same terms for different conceptual entities on conceptual understanding of heat and temperature.

This study not only gives signs of the positive short-term impact of facilitating metaconceptual processes but also long-term a potential positive impact on students' conceptual understanding Students' regression to their initial alternative ideas short time after the instruction is an important problem in science learning (Georghiades, 2001). Monitoring the changes in ideas is a metaconceptual process that may potentially play a significant role in maintaining the durability of learners' current ideas because one's monitoring of the changes in ideas has the capability to generate information about the validity of initial and current ideas. During the post-interview, the student in this study displayed evidence for the coexistence of her initial and current ideas about forces and for her acquisition of knowledge about the validity of their initial and current ideas:

R: What happens to your old idea after you accept a new idea? Is it still there or you just forget it?

Lisa: If I really form the initial idea as I did in inertia it is still there. But like in some other ideas, concepts, if I didn't form the initial idea or if the initial idea is so much the same as the what the scientifically accepted one is…

R: Do you still use your initial idea?

Lisa: For inertia?

R: Inertia or other concepts? Whenever you are exposed with a situation where for example forces acting on objects do you still think about your initial idea ofinertia sometimes?

Lisa: Yes.

R: Could you describe what you think when you are asked a question about forces acting on objects, supposedly a ball is thrown up for example?

Lisa: I think about my idea of inertia. It comes to my mind still but I know that I changed it and it is accepted as wrong answer. And I give the right answer. (Excerpt from post-interview)

In the excerpt above, Lisa maintained that her well-formed initial ideas about forces came into her mind whenever she was asked a question about forces acting on objects. For example, she remembered her initial idea of inertia (acquired force in the direction of object's motion keeps the object moving) when she was asked forces acting on objects. When this happens, she realized that she changed her initial idea of inertia. Lisa was not only aware that her current idea was different from her previous understanding of inertia, but she was also able to recognize that her initial ideas were wrong. Having information about the validity of her initial and current ideas, Lisa claimed that she used her correct idea when she was asked. Acquiring information about the validity of previous and current ideas would become available to learners when they remember their initial ideas. As long as students retain this kind of information in their memory, the restructuring in learners' conceptual understanding would be more permanent. Her scores on the FCI administered nine weeks after the metaconceptual teaching interventions reflect the durability of her scientifically acceptable ideas. Out of the 30 items she could answer 27 item following the instruction and 25 items nine week after the instruction correctly. This finding indicates that even nine weeks after the instruction Lisa retained most of her scientifically accepted conceptions that she constructed throughout the metaconceptual teaching interventions. The long-term impact of facilitating metaconceptual processes on students' conceptual understanding was also reported in Blank's (2000) and Georghiades's (2004) studies.

The findings show that the participant of this case study engaged in a variety of metaconceptual processes ranging from simple awareness of her ideas to more sophisticated higher-order thought processes. The level of sophistication at which the student engaged in a particular type of metaconceptual process differed from one context to another. For example, while Lisa was able to provide justification as she reflected on the plausibility of an idea in one context, she did not provide any justifications as she evaluated the same idea in another context. These findings indicate that metaconceptual thought is not a "all or none" phenomenon, but rather these processes are in the repertoire of learning behaviors of students, the content, the frequency, or the level of their sophistication of them may vary from one context to another, and they can be activated when structured opportunities were provided for the students.

This study strengthens the claims of introducing instructional activities that facilitate students' engagement in metaconceptual processes into classroom settings. The teaching-learning environment created in this study was different from traditional instruction in which students sit passively, listen to the teacher, and memorize facts about the physical world. When appropriately facilitated students' have the ability to become aware of their conceptual structure, monitor their concept learning and evaluate ideas coming from different sources. Metaconceptual thought should not be disregarded at the expense of the loaded science content but rather it should be an integral part of the curriculum.

It should be kept in mind that the conclusions drawn from this study are limited only to a single student observed for this case study. Investigating students' metaconceptual processes in other subject areas within different age levels may potentially produce scientific knowledge about students' abilities to engage in metaconceptual processes and the interaction of the metaconceptual processes with the subject matter. Further research that investigates the metaconceptual processes of multiples cases would enable us to grasp a more complete picture of the nature of higher order thinking that are acting on learners' conceptual systems and its contribution to the concept learning.

REFERENCES

Beeth, M. E. (1998). Teaching for conceptual change: Using status as a metacognitive tool. *Science Education, 82* (3), 343-356.

Blank, L. M. (2000). A metacognitive learning cycle: a better warranty for student understanding? *Science Education*, *84*, 486-506.

Brown, A. L. (1978). Knowing when, where and how to remember: A problem of metacognition. In R. Glaser (Ed.), *Advances in instructional psychology* (Vol.1, pp. 77-165). Hillsdale, NJ: Erlbaum.

Brown, A. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert, & R. H. Kluwe (Eds.), *Metacognition, motivation, and understanding.* Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Slotta, J. D. & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction, 4,* 27–43.

Clement, J. (1983). A conceptual model of discussed by Galileo and used intuitively by physics students. In D. Gentner & A. Stevens (Eds.), *Mental models* (pp. 325-339). Hillsdale, NJ: Erlbaum.

diSessa, A. (1993). Toward an epistemology of physics. *Cognition and Instruction, 10(2-3),* 105-225.

Driver, R., & Easley, J. (1978) Pupils and paradigms; a review of literature related to concept development in adolescent science students. *Studies in Science Education, 5,* 61-84.

Ferrari, M., & Elik, N. (2003). Influences on intentional conceptual change. In G. M. Sinatra, & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 21-54). Mahwah NJ: Lawrence Erlbaum.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34* (10), 906-911.

Flavell, J. H. (1981). Cognitive monitoring. In W. P. Dickson (Ed.*), Children's oral communication skills* (pp. 35-60). New York: Academic.

Garner, R. (1987). *Metacognition and reading comprehension.* Norwood, NJ: Ablex.

Georghiades, P. (2004). Making pupils' conceptions of electricity more durable by means of situated metacognition. *International Journal of Science Education, 26*, 85-99.

Hacker, D. J. (1998). Definitions and empirical foundations. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 1−23). Mahwah NJ: Erlbaum.

Hake, R.R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66* (1), 64-74.

Henderson, C. (2002). Common concerns about the force concept inventory. *Physics Teacher, 40,* 542-547.

Hennessey, M. G. (1999). *Probing the dimensions of metacognition: Implications for conceptual change teaching-learning.* Paper presented at the annual meeting of the National Association for Research in Science Teaching. Boston, MA.

Hennessey, M. G. (2003). Metacognitive aspects of students' reflective discourse: Implications for intentional conceptual change teaching and learning. In G. M. Sinatra, & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 103-132). Mahwah NJ: Lawrence Erlbaum Associates.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*, 141-158.

Kuhn, D., Amsel, E., & O'Loughlin, M. (1988). *The development of scientific thinking skills*. San Diego, CA: Academic Press.

Mason, L., & Boscolo, P. (2000). Writing and conceptual change. What changes? *Instructional Science, 28*, 199-226.

McCloskey, M. (1983) Naive theories of motion. In D. Gentner, & A. Stevens (Eds.), *Mental models* (pp. 229-324). Hillsdale: Erlbaum.

Pintrich, P. R., & Sinatra, G. M. (2003). Future directions for theory and research on intentional conceptual change. In G. M. Sinatra & P.R. Pintrich (Eds.), *Intentional conceptual change* (pp. 429-441). Mahwah NJ: Erlbaum.

Posner, G. J., Strike, K.A., Hewson, P.W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*, 211-227.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7,* 351-371.

Scott, P., Asoko, H., & Driver, R. (1992). Teaching for conceptual change: A review of strategies. In R. Duit, F. Goldberg, & H. Niedderer (Eds.), *Research in Physics Learning*: *Theoretical Issues and Empirical Studies* (pp. 310-329). Kiel, Germany: University of Kiel.

Ueno, N. (1993). Reconsidering p-prims theory from the viewpoint of situated cognition. *Cognition and Instruction, 10(2-3),* 239-248.

Vosniadou, S (1999). Conceptual change research: State of the art and future directions. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New perspective on conceptual change* (pp. 3-14). Oxford, U.K.: Elsevier.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4,* 45-69.

Vosniadou, S. (2002). On the nature of naïve physics. In M. Limon & L. Mason (Eds.)*, Reconsidering conceptual change: Issues in theory and practice* (pp. 61-76). Amsterdam: Kluwer.

Vosniadou, S. (2003). Exploring the relationship between conceptual change and intentional learning. In G. M. Sinatra, & P. R. Pintrich (Eds.), *Intentional conceptual change* (pp. 377-406). Mahwah NJ: Lawrence Erlbaum Associates..

White, R., & Gunstone, R. (1989). Metalearning and conceptual change. *International Journal of Science Education, 11*(Special Issue), 577-586.

Wiser, M., & Amin, T. (2001). Is heat hot? Inducing conceptual change by integrating everyday and scientific perspectives on thermal phenomenon. *Learning and Instruction, 11,* 331-355.

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The History of Development of Turkish Elementary Teacher Education and the Place of Science Courses in the Curriculum

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Turkey has more than 130 years of experience of elementary teacher education in formal meaning after opening of the first elementary teacher school. During this time period, approximately in every 10 years there were some major changes based on the level of elementary teacher schools such as middle school, high school or higher education institutes, the number of years of education, and the name and weekly hours of courses. The average percentage of weekly hours of science or science related courses is around 9.69%. The highest percentage of weekly hours of science courses in the history of Turkish elementary teacher schools with the range of 12.1% and 16% belongs to the beginning of Republic or Atatürk era between 1923 and 1938 years. This also shows the main approach of the era of Ataturk to the education as well as elementary teacher education. The lowest percentage of weekly hours of science related courses as 2.1% corresponded to the two-year higher education institutes during 1970s. It shows that this period was the most neglected, and politicized era in Turkish elementary teacher preparation and education. On the other hand, Turkish elementary teacher education has begun to show acceleration in changing and takes its proper place in both qualitative and quantitative meaning, such as increasing the level of elementary teacher education schools to four-year college level institutions and the percentage of weekly hours of science related courses.

Keywords: History, Elementary, Teacher Education, Science Courses, Turkey

INTRODUCTION

The Every nation has its own history of education despite some similarities with others. Generally, the educational history of a nation mainly deals with instructional and educational activities from a historical perspective (Akyuz, 1993, p. 1). In this paper, there is no purpose to give a general summary of the History of Turkish Education but to show the history of Turkish teacher education, particularly elementary teacher education and preparation. In this context, it is necessary to underline some important events and eras affected elementary teacher education and preparation from historical perspectives. The main purpose of this paper is to examine the historical development of Turkish elementary teacher education and preparation as well as the place and importance of science courses in the whole curriculum from the past to the present. Before the beginning of the history of elementary teacher schools and the place of science courses in Turkey, it would be necessary to give a brief history of Turkish Education History until the opening of the first elementary teacher schools in 1867.

The history of Turkish education goes back to early centuries. In the Turkish history, some important events influenced education, such as; dispersion of Turks from Central Asia to the Indian peninsula, around the Caspian Sea, and the west, and converting to Islamic

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religion in 9th century. When they founded an empire called the Great Seljuks around 10th century in Iraq and Iran, the most important influence seen on the Turkish people was the effects of Islamic religion. Consequently, many cultural and religious elements began to be seen in every aspect of life of Turks. With the newly conquered places and established states, education life and system were almost under the complete influence of Islamic religion and civilization and also, some elements of Persian and Arabic cultures. Like every state, they needed educated people for the sake of state. Eventually, a few numbers of schools (called Medrese) taught some essential knowledge for state affairs and religious purposes could be seen during the Great Seljuk Empire, Anatolian Seljuk State and the Ottomans (Akyüz, 1993). One of the famous of these schools was the Nizamiye Medrese founded near Baghdad in 1067 (Turan, 1969). After the disintegration of Anatolian Seljuk State, the Ottoman Dynasty later became one of the most powerful empires in the history and the same education system survived until 18th century. Until that time, it is difficult to say that a special school designed for teacher preparation was established in the Ottoman Empire. Only during the reing of Sultan Mehmet II, also called Conqueror Sultan Mehmet, in Istanbul there were the medrese studends who were supposed to become a kind of elementary teachers were taught some kinds of courses, such as instruction methods but this type of medrese was not seen after Conquer Sultan Mehmet (Ozturk, 1996). To sum up the teachers of low-level schools (mekteps in Turkish) were the heads of mosques (Imam or Hoca in Turkish) in many places. The teachers who were going to teach in medreses (high level schools) graduated from medreses after a long education period and additionally they needed to be certified by certain authorities to become instructor. In the Medreses, in addition to religious courses, some calculation and algebra courses were taught but not science related courses, especially afte Conquer Sultan Mehmet era (Adivar, 1991, p. 57). According to some historians, by the late of 16th century, it could be found few scholars dealing with science activities, such as astronomy but they were not well respected by the other scholars. Unfortunately, at the end, some of those famous scholars paid the results of their activities with their lives, for example Molla Lutfi (Bahadir, 1996). In the result, general attitudes toward the people who were dealing with or studying some sort of science related courses, apart from some medical and astronomy courses, were not good and not well respected especially after the last half of 16th century (Akyuz, 1993, p. 53 and 61).

When the power balance began to shift from the Ottoman Empire to the western powers at the end of the last half of 17th century, the Ottoman Empire entered a new state or era called the stagnation period. After one hundred years later, around the second half of 18th century, the Ottoman Empire realized the military superiority of some European countries. The first western styles schools opened during the second half of 18th century were mainly military schools due to reasons mentioned above (Kodaman, 1991, p. 1-2; Adivar, 1991, p. 221; Atuf, 1931, p. 50). However, for these schools there was a need of adequately educated student source. Traditional school system was not capable of providing this kind of students (Kocer, 1967, p. 6-7). The proclamation of decree of Tanzimat (reorders or revisions) in 1839 accelerated these changes in the Ottoman Empire. It was seen a new school type called Rustiye, a kind of middle school, in order to foster students for the schools mentioned above for the first time in the Ottoman Empire (Ozturk, 1996, p. 4 and Kocer, p. 6). Additionally, in 1869 with the acception of the decree of the general education policy (Maarifi-i Umumi Nizamnamesi), these kinds of schools began to disseminate throughout of the Ottoman Empire (Akyuz, 1993, p. 162-164). On the other hand, the preparation of teachers for these schools was a strong necessity but there was no special teachers' school for these schools. Finally, it was a turning point in the history of Turkish education that on the 16th of March, 1848 for first time a teacher school was opened for the needs of newly opened middle schools (Ozturk, 1996, p. 4, Kafadar, 1997, p. 96). After this date, the history of Turkish teacher education began to make progress. Even the first years, the school was not enough for quality and quantity for teacher education but it was a beginning. This beginning later made the beginning of other teachers' school called the school of elementary school teachers in 1868 (Akyuz, 1993, p. 158).

The First School of Elementary School Teachers during Reorder (Tanzimat) and First Constitutional Era

Educational reforms in the Ottoman Empire began from up to down in the second half of 18th century as the classification of the high school or college level military and technical schools. As mentioned above, when the need of educated students before coming to these kinds of schools increased, it was thought to open middle level schools for upper level schools. After opening middle level western style schools, there was a need for teachers. Consequently, it was followed by the openning of the first teachers' school in the history of Turkish education in 1848. Finally, this movement was ended with the revision of traditional elementaryschools (Sibyan Mektepleri) and opening a school of elementary teachers on 15th of November, 1868 (Dilaver, 1994 and Bilim, 1998). This school was only for two years and the name of courses are presented in the following table 1.

Table 1. The name of courses of the first opened elementary teacher schools in 1877 (Akyuz, 1993, p. 158 and Kocer, 1967, p. 24-25)

Teaching Methods
Calculation
Geography
Persian
Turkish Language and Grammar
History of the Ottoman
Algebra
Writing

Later, the female elementary and middle teachers' school was opened and its courses were almost the same as the male elementary teachers' school's courses. After that, these teachers' schools began to be seen in other major cities, beyond Istanbul, the capital of the Ottoman Empire.

There were almost no science-related courses in the first elementary teachers' schools' curriculums at the beginning. It would be thought that there was no need for science-related courses for teacher candidates in these teachers' schools. Another reason would be that these schools were still under the pressure from the traditional schools because the teachers of these elementary teachers' schools mainly coming from traditional school systems (Medrese) and courses mostly pertinent to religious subjects (Akyuz, 1993, p. 161).

In 1904, middle and elementary teachers' schools were converged under one school as a kind of primary teachers' schools and the level of these schools could be considered as a high school level (Ozturk, 1996, p. 16). The name of courses and their weekly course hours are listed in the table 2 (Kocer, 1967, p. 37 and Berker, 1945).

In 1904, the revised curriculum of elementary teachers' schools included a sort of science course, translated to English as a physical science course for the first time. When compared to the first curriculum of elementary teacher schools, the new curriculum seems to show some elements of western influence as there was a foreign language course and a physical science course. The percentage of weekly hours of physical science course was around 5.4%. However, Hasim Pasha, Minister of Education in 1906, wrote Sultan Abdulhamid a letter in which Ilm-i Esya (Physical Science) Course was not a necessary course so that it would be abolished from the program (Akyuz, 1993, p. 220). The reason to abolish the course was that it was considered as an unnecessary course for students.

There was no major change until the Second Constitutional Era (1908). In 1876, as the first time a constitution was promulgated and the duration of this period was only one year. The first Ottoman Parliament

Table 2. The Name of Courses of Middle and Elementary Teachers' Schools and Weekly Hours in 1904

The name of Course	*First Year*	*Second Year*
The Noble Qur'an and Its Reading	4	3
Turkish and Grammar	3	-
Teaching Methods	-	1
The Art of Fine Hand Writing	-	2
Arabic	2	2
Persian	2	2
French	-	1
Calculation	2	2
Physical Science (*İlm-i Eşya*)	**1**	**1**
General Ottoman Geography	2	2
The History of Islam	2	1
Writing	1	1
Total	**19**	**18**

was abolished when the Turkish-Russian War started in 1877, and the country began to be governed by the absolute rule of Sultan Abdulhamid until 1908. During this time the number of primary teachers' schools, out of Istanbul, was increased. However, there was no significant change in these schools' curriculum.

During the Second Constitutional Era

In the late times of the Ottoman Empire, there were several ideas or approaches in order to save the Empire. Generally, some intellectuals, who especially studied in Europe, believed that the Empire could be saved through education and reaching the vast areas of the Empire by increasing public literacy level. Therefore, education reforms began to make progress. One of them was Temporary Primary Education Law accepted in 1913. According to this law, it was planned to open one teachers' school in every province center and in some province centers, teacher's schools for girls (Binbasioglu, 1995 and Dilaver, 1994). However, in this period there were many internal and external problems. The most important one was the First World War. During this time period, also, the number of years of education for the primary teacher schools was increased from three years to four years. There were also some new courses in school curriculum, some of which were related to science area (Ergun, 1996, p. 318). However, this change was not implemented fully due to the First World War. Additionally, the first boarding teachers' schools were thought to be opened in rural areas or

Table 3. The Name of Courses in the Primary Teachers' School as Weekly Hours in 1913 (Kocer, 1967, p. 53-54)

Courses	1st Year	2nd Year	3rd Year	4th Year
Qur'an and Religious Knowledge	2	2	2	2
Teaching Methods and Applications		1	2	12
Punctuation and writing rules	5	3	2	
Ottoman language	2	3	2	2
Reading and Memorization	3	2	2	3
French	1	1	1	
Calculation and Algebra	3	3	3	2
The Ways of Keeping Notes on Accounting			3	
Geometry		2	2	1
Geography	2	2	1	1
Cosmography (Astronomy)*				1
History	2	2	2	2
Physics*		2	1	1
Chemistry*			2	
Natural Science *	3	3		
Health Knowledge*				2
Theoretical and Applied Agriculture and the History of Economy	2	3	3	3
Civilization and Law	1	1	1	
Hand Tools Course	1			
Fine Writing	1	1	1	
Music	2	1	1	
Picturing	2	2	2	1
Hand Activities	2	2	2	2
Physical Education	2	2	2	2
Total	36	35	36	36

*Science/related cources.

villages. In table 3, the name of courses and weekly hours are listed at the above.

This school curriculum seems to be as much as contemporary at its time for primary teachers' school in the Ottoman Empire but as mentioned above, it could not applied due to the First World War. The total number of hours of science related courses was 14 hours a week and the percentage of science related courses was 9.7% (14/143) in the total number of weekly hours of courses for four years. Additionally, the number of primary teachers' colleges was increased to16 and was spread out to the some major cities of the Ottoman Empire in 1914. It is necessary to remind that these primary teachers' schools seem to be a kind of upper secondary school. However, there was no clear evidence of the kinds of students that could be accepted to this primary teachers' schools and of the category under which this schools could be placed (Ozturk, 1996, p. 27). However, some times these schools were under a department of college level teachers' schools during 1913-14 in Istanbul, according to the official guide and policy of teachers schools prepared by the government (Ozturk, 1996, p. 26). Also, their graduates were mostly appointed to the elementary schools at that time even their names bear the primary teachers colleges or schools.

Unfortunately, many educational reform movements could not bring about some expected results in education, especially in teacher education. After the promulgation of the second constitution era in the Ottoman Empire, there were many internal and external problems. The most important one was the collapse of the Ottoman Empire as a result of the First World War. As a result of these developments, many elementary teachers' schools in rural area were closed or postponed their instruction due to financial reasons, lack of qualified instructors, internal and external problems such as wars and the disintegration of the Ottoman Empire.

Primary Teacher Schools After 1923 (Republic Era)

After the collapse of the Ottoman Empire, the mainland, Anatolia, was under a threat of invasion by other countries. With the liberation war, Turkey gained

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Table 4. Curriculum of Primary (for elementary) Teachers Schools in 1924

Courses	**1st Year**	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**
Religious Knowledge	2	2			
Turkish and Literature	6	5	3	3	3
History	2	2	2	2	
Sociology					2
The knowledge of Motherland				2	
Education and the history of Education				3	4
Teaching Methods and Applications					9
Calculation	3	2	2		
Geometry	2	2	1		
Algebra				2	
Physics		2	2	1	
Chemistry		1	2	1	
Zoology				2	
Botanic		2			
Agriculture/Physiology *			2		
General Health Control and School Health Control				2	1
Cooking*				1	
Geography	2	1	2	1	
Art	2	1	1	1	1
Hand Projects			1		
Writing	2	1			
Music	1	1	1	1	1
Physical Education	1	1	1	1	1
Foreign Language	3	2	2	2	2
Vocational Courses for Girls*	1	2	4	4	4
Total	28	28	28	28	28

*These courses for only Girl Teachers Elementary Schools

her liberation and independence, under the leadership of Mustafa Kemal. Finally, there was a young republic, founded at the 29th of October, 1923. With the following of establishment of the republic, there were some reform movements in many areas and one of the most important reforms was the unification of education. With this law all schools and foundations related to education were unified under the ministry of national education and traditional schools, medreses, were abolished permanently. The other one was that elementary education was compulsory and free (Kocer, 1967, p. 67).

One of the important aims of the young Turkish republic was to disseminate the basic education to all of the citizens since the majority of people living in rural area were still illiterate. In 1924, the committee of science considering education made some important decisions that 1) the number of grades for elementary schools was five, 2) the duration of elementary teachers' schools was increased from four years to five years, 3) their curriculum was mostly changed and revised based on the ideas of the young republic. The first curriculum of Primary Teacher Schools could be seen in the following table after establishing the Republic in 1923.

This is the first elementary teachers' schools' curriculum after the foundation of the Republic of Turkey. When two curriculums as in 1914 (Table 3) were compared, some differences can be easily discerned that the percentage of science courses increased from 9.7% to 12.1% (17/140).

The other difference between two school curriculums in 1914 and 1924 was that it showed the first signs of secularization in school curriculums as it decreased the number of religion related courses (Table 3 and 4).

The levels of these elementary (or some times they could be called primary) teachers' schools could be classified as a combination of middle and secondary schools at that time (Dilaver, 1994, p. 32). As mentioned above, the majority of population was still living in rural area, especially in villages. During this time, the newly established republic was inviting some foreign educators

Table 5. Weekly Hours of Courses of the Primary Male and Female Teachers' Schools in 1938

Courses	1st Year	2nd Year	3rd Year
Literature	3	3	3
Pedagogy		2	1
Psychology**	2	2	
The History of Education	2	2	
Teaching Methods and Application			2
Sociology		2	7
History			2
Geography	2	2	2
Mathematics	2	1	2
Physics and Chemistry	4	4	1
Natural Sciences and Health */**	4*/2**	4*/2**	3**
School Health */**	2*	2*	1**
Foreign Language	3	2	
Gymnastics	1	1	1
Hands on Activities	2	1	1
Music	1	1	1
Military information */**	2/1	2/1	2/1
Sowing**	2	1	1
Child Care**		1	1
Home Administration**			1
Drawing**	1	1	1
Total */**	29*/30**	29*/30**	29*/30**

* For male primary teacher schools
** For female primary teacher schools.

to Turkey such as John Dewey in 1924. In Dewey's report, it was mentioned that for rural areas or villages it was necessary to open another type of village teacher school to meet the needs of villagers (Turan, 2000). This fact led to another discussion to open a different elementary teacher school for village schools in 1925. As a result of this movement, with the minister of education, Mustafa Necati, in 1927 two village teacher schools were opened with a three-year instruction period after elementary school graduation (Kocer, 1967, p. 91). The new village teacher schools' curriculum showed some pragmatist approach in elementary teacher education. This was suggested by John Dewey that education should meet the needs of people according to where they live. Therefore, special attention was paid to agricultural courses and their applications. For example, in 1924 primary teacher schools for male students there was only a two-hour in a week agriculture course but in village teacher schools there was a six-hour-week agriculture course. On the other hand, the ratio of science courses in the village teacher schools seems to be decreased, (compared to) primary teacher schools. For example, the percentages of science courses in primary teacher schools and village schools were 12.1% (17/140 hours/five-year total weekly hours) and 8.6% (10/116 hours/three-year total weekly hours), respectively (Table 4 and Kocer, 1967, p. 91-92). This movement could be called as the beginning of a dual system in the Turkish elementary teacher education.

Primary Teacher Schools after Ataturk Era (1938)

In 1938, elementary teachers' schools were reorganized that their education periods were three years after graduation from a middle school. The curriculum of these schools was as the following.

The total numbers of weekly hours of science related courses in primary teachers' schools for male and female is 14% (13/87) and 16% (15/90), respectively (Kocer, 1967, p. 106-107). This primary teacher school curriculum seems to be the most secular due to no courses affiliated to religion and the highest proportion of science related courses between 14% and 16%.

In the history of Turkish Republic, the period from 1923 to 1938 is generally called Ataturk's era. For the education history of Turkey, this era also means secularization and unification of education (Ozodasik, 1999 p. 44 and 117; Cumhuriyet Doneminde Egitim (Education in the Republican Era), 1983, p. 114). When the Turkish Republic was founded, one of the most important goals of the Republic was to establish a

Table 6. The Weekly hours of courses taught in the Village Institutes after 1947 Revision

Courses	1st Year	2nd Year	3rd Year	4th Year	5th Year
Turkish	4	4	4	4	4
General Psychology				2	
Child and Young Psychology					1
Pedagogy (Educational Science)				1	1
General Teaching Method				2	
Special Teaching Method and Application					6
Sociology					2
The History of Education					1
History	2	2	1	1	1
Geography	2	2	1	1	1
Civic		1	1		
Mathematics	5	3	3	3	
Physics		2	2	2	
Chemistry		2	2	1	
Natural Science	2	2	2	2	
School Health					1
Writing	1	1	1		
Drawing or Art	1	1	1	1	1
Hand Work		1	1	1	
Physical Education and National Plays	1	1	1	1	1
Music	2	2	1	2	1
Military			1	1	1
Child Care and Home Administration				1	1
Cooperating					1
Total hours of Agriculture Courses and Applications*	12	10	11	9	10
Total hours of Vocational Courses and Applications*	12	10	11	9	10
General Total Hours in a Week	44	44	44	44	44

* These courses consisted of different agriculture and vocational courses and their applications such as; Agronomy, Horticulture, Zoo-technique, Bee Keeping, Fisheries, Black Smith, Carpenter, Home Building, Concreting, Weaving, etc.

state based on the contemporary values and to foster and make her citizens think scientifically (Cetin, 2000 p. 664-665, Yilman, 1999, p. 10, Kazamias, 1966, Turan, 2000).

Village Institutes between 1940 and 1953

For the preparation of elementary school teachers, sometimes called classroom teachers, village institutes have an important place in the history of Turkish teacher education These institutes have different meanings and functions. Since 1868, elementary teachers' schools passed from different phases or eras. The first elementary teachers schools founded in 1868. A two-year primary teacher school was opened in 1904. A four-year primary teacher school was opened in 1913. A five-year primary teacher school was opened in 1924. A three-year primary teacher school was opened after middle school in 1938 as a high school level. Despite the changes in duration and curriculum of elementary teachers' schools more than 70 years, they were beyond to meet the need of elementary school teachers of Turkey in 1940. In order to convey the principle of Turkish Revolution and Republic to every corner of the country, the republic needed idealist elementary school teachers who could work in rural areas. The current teachers at that time were not much familiar to rural areas or village life (Turan, 2000). Additionally, teachers who had urban life experiences did not want to go to villages. However, one of the important goals of the young Turkish republic was to educate and elevate life standards of villagers as well as disseminate the principles of Turkish revolution while around 90% of the village population were still illiterate (Akyuz, 1993 p. 339). A different elementary teacher school for village elementary schools called village institutes came to life in 1940 (Dilaver, 1994 p. 34-35 and Dilaver, 1997 p. 6-7). According to Turan (2000), John Dewey's report upon Turkish Education System suggested that school curriculums should meet the needs of local communities. From this point, according to the law the majority of students of village institutes had to come from village elementary school selected among talented or top graduates. These students had to work in villages for at least 20 years after graduation (Kocer, 1967 p. 116-117). The graduates of village institutes were not only elementary school teachers but also agriculture and health technicians, mechanics, or carpenters of villages (Kocer, 1967, p. 117). From 1940 to 1948, the number of village institutes increased to 22. According to Village Institute Law, a student who was accepted to the institute had to come from a village school and after graduation he/she had to go to a village school at least 20 years compulsory service . Also, instead of regular salary like urban elementary school teachers, they had to use designated agricultural fields by the government in a village to make living. Only a small amount of salary and some agricultural equipment were given to these village school teachers (Dilaver, 1997, p. 73). A few years after the opening of the village institutes, the criticism began for the village institutes mostly related to the load of elementary school teacher. The criticism was that a teacher being able to do all these jobs mentioned above seemed impossible. The weekly hours of courses of these village institutes is given at the table 6.

After elementary school graduation, the most talented village boys and girls were admitted to the village institutes to become an elementary teacher as well as a village trainer or technichian with the following 5 years education period with the equivalency of high school graduation. As seen in the table 6, almost half of weekly courses belong to agricultural and vocational courses. However, the percentage of science courses in the village institutes is 8.6% (19/220). This percentage shows a sharp decrease in the ratio of science related courses while giving a special attention to agriculture and vocational courses in the village institutes (Dilaver, 1997, p. 58-59). In 1953, the curricula of primary teacher schools and village institutes were converged under one curriculum as female and male primary teacher schools and village institutes. Additionally, the number of school years was increased from 5 years to 6 years. With these developments and some additional political and education reasons, some of which were that a person could not do all the training and teaching jobs at the same in a village, village institutes were converted to the primary teacher schools and their curricula in 1954. As a result, the village institutes and a special village elementary school teacher preparation era were ended. They took their places in the history of Turkish education. As could be seen in the table 6, in a short time in these schools, a student who graduated from a village elementary school with good grades could be an elementary school teacher as well as a village trainer with five-year education. Also, a student in a village institute was supposed to learn almost every thing with very heavy curriculum and 44 hour-courses in a week. This approach, in the elementary teacher education, seems to be impossible in today's standards. On the other hand, instead of abolishing village institutes, they could be revised and updated under the conditions of Turkey so that this experience would not have been a historical case in the preparation of elementary school teachers of Turkey.

Six-year Primary Teacher School Era between 1954 and 1970

With the closing of village institutes, one school and teacher preparation system for elementary schools began in 1954. As a result of closure of village institutes and combining with the current primary teacher schools in 1954, the number of years of primary teacher schools was increased from five to six years. It means that the level of primary teacher schools was the equivalent of high schools. In the table 7, the name and weekly hours of courses could be seen between 1954 and 1970.

After 1954, elementary school teachers began to graduate as a total of 23 hours science courses of six years education. The percentage of science courses at the total courses is 10.6% (23/215). This percentage seems to have a slight increase when compared to science courses in the village institutes (8.6%, Table 6). The reason for this slight increase would be because of elimination of some field base courses and their applications from the curriculum. On the other hand, the general trend for the percentage of science related courses seemed to be around 10% on the primary teacher schools until 1970. The other significant part of this curriculum was the absence of foreign language courses. Before closing high school level primary teacher schools, the number of years of education increased to seven years between 1970 and 1974. The percentage of science courses increased from 10.6% to 13.8% due to increasing of school years and weekly hours of science courses (Dilaver, 1997, p. 156).

Higher Education Era in Elementary Teacher Education as Two-year Education Institutes between 1974 and 1992

According to the new national education law in 1973, teachers should be prepared and educated at the college level or in higher education after high school graduation. With this new law, elementary school teacher preparation and education at the high school level was ended up in the history of Turkish elementary school teacher education. Some of the current primary teacher schools were converted to normal high schools as a kind of boarding schools called teacher high

Table 7. The name and weekly hours of courses in primary teacher schools between 1954 and 1970 (Kocer, 1967 and Dilaver, 1997).

Courses	*Years*					
	1	**2**	**3**	**4**	**5**	**6**
EDUCATIONAL SCIENCES GROUP						
Introduction to Psychology				2		
Educational Psychology					2	3
Instructional Method and Applications					2	6
Educational Sociology					1	2
Organization and Administration						1
Seminar					1	2
TURKISH LANGUAGE AND LIT. GROUP						
Reading	3	2	2	1	1	
Grammar	1	1	1	1	1	
Composition	1	1	1	1	1	1
The History of Turkish Literature				1	1	
Child Literature						1
SOCIAL SCIENCES GROUP						
History-Geography and Social Sciences	4	4	4			
History				2	2	1.5
Geography				2	2	1.5
NATURAL SCIENCES GROUP						
Nature and Science	**3**	**4**	**5**			
Physics				**2**	**2**	
Chemistry					**3**	
Biology and Health Sciences					**2**	**2**
Mathematics	4	4	4	4	3	
National Defense				1	1	1
Religion				1	1	
Physical Education	2	2	2	2	2	2
Music	2	2	2	2	2	2
Art (Drawing, Painting, and Fine Writing)	3	3	3	2	2	2
Work and Home Working	6	6	5	5	3	3
Agriculture	3	3	3	4	3	3
Free Studies and Works	3	3	3	3	3	3
Total	**35**	**35**	**35**	**36**	**37**	**37**

schools and the others were closed. For the first time, two-year education institutes (four semesters) were opened at the junior college level for elementary school teachers after high school graduation in 1974.

The number of two-year education institutes was 50 and mostly opened in the province centers. However, the time period between 1974 and 1980 was the increasing social unrest and many of those institutes could not function properly. In 1981, their numbers were decreased to 17. In the following year, 1982, these education institutes were named as education high schools at junior college level. This is another turning point on the elementary teacher education in Turkey that for the first time the elementary teacher schools were under the university system and not administered and controlled by the ministry of national education any more (Akyuz, 1993, p. 332). In the following table 8, the name of courses of two-year education institutes are given in 1980 (Akyuz, 1993, p. 333).

In two-year education institutes for elementary school teachers, there was no required science course but only science teaching course as a core course. If an elementary school teacher candidate wants to take a science course, he/she could take a selective science course. When the science teaching course is classified under science course section, the minimum ratio of science course is 2.8% (3/104). This is one of the lowest ratios of science courses in elementary teacher education. One of the reasons for this ratio of science course would be that elementary school teacher candidates graduated from a high school were assumed to have had enough science background. Therefore, it

Table 8. The name of courses of two-year education institutes or education high schools (Junior Education Colleges)

Courses	1st Year		2nd Year	
	Fall	Spring	Fall	Spring
General Culture Courses				
Turkish and Composition	2	2		
The history of Thinking		3		
Introduction to the Economy		3		
The History of Revolution			2	2
Foreign Language	2	2	2	2
Research				3
Elementary Education Courses				
Teaching of Life Science				2
Teaching of Turkish			2	2
Teaching of Social Science				3
Teaching of Science			3	
Teaching of Mathematics	3			
Teaching of Religious				2
Music and Teaching	2	2	2	
Teaching of Physical Education and Play	2	2	2	
Teaching of Art, Drawing, and Fine Writing	2	2	2	
Student Teaching*				
General Education Courses				
Introduction to Education	2			
Educational Psychology		3		
Educational Sociology			2	
Curriculum and Methods	3			
Educational Administration				2
Assessing and Evaluation			3	
Guidance				2
Pre-school Education or Special Education		2	4	3
A Working and Technical Education Course (Handcraft, Agriculture, Health, Electric, etc.)	2	2	2	2
A selective course (Mathematics, Turkish, etc.)	3	3	3	
Total	**24**	**26**	**29**	**25**

*Approximately 15 days in the fourth semester as a student teacher in an elementary school

was assumed that there was no need for these courses again. On the other hand, these two-year education institutes, later renamed "the two-year education high schools" under universities in 1982 (Yilman, 1999, p. 33 and 61, Basaran, 1994, p. 111) as a junior college accepted high school graduate students who had, mostly, very weak science background and low achievement.

In 1989, with a decision of Turkish Higher Education Council (THEC), for the first time elementary schoolteachers would be graduated with a bachelor's degree from a college of education (Turan, 1995, p. 13). This change was another turning point in the history of elementary school teacher education in Turkey because for first time an elementary school teacher was going to graduate from a four-year college of university with a bachelor's degree. In the following table 9, the name of courses and credit hours of a four-year elementary teacher education department was listed as an example in 1994 and 1998.

Despite some differences based on the names and credit hours of courses of some elementary education departments, generally their curricula were close to each other in 1994, 1998 and 2006. The total number of the credit hours of courses of the college of Usak Education's elementary education department was 166 credit/hours. Only 16 credit-hours courses belong to science courses including solid science as well as science teaching method courses and their ratio is 10% (16/160). When science teaching method courses are not included, the ratio is 6.25% (10/160).

Table 9. The name of courses and their credit hours of a four-year elementary teacher education department of College (Faculty) of Usak Education, Afyon Kocatepe University in 1994 and 1998

The Name of Courses	1st Year		2nd Year		3rd Year		4th Year	
	1st	2nd	3rd	4th	5th	6th	7th	8th
Principles of Ataturk and the History of Turkish Rev.	3	2						
General Geography-I/ Introduction to Geography*	2							
Basic Mathematics I and II	2	2						
Teaching of Art, Drawing, and Writing I-II-III-IV	2	2	2	2				
Statistics	2							
Introduction to Education	2							
Computer Using I and II, Computer Assisted Teaching	2	2	2					
Turkish Literature I and II	2	3						
History I and II	2	2						
Teaching of Physical Education and Play I, II and III	2	2				3		
Foreign Language	3	3						
Turkish History		2						
Development Psychology		2						
Geography of Turkey		2						
Geography of Countries			2					
Basic Chemistry*/General Chemistry**		**2*/3****						
General Biology I-II*/ Living **/	**3****		**2***	**2***				
Basic Physics I-II*/Basic Physics/**			**2*/3****	**2***				
Culture of Religion and Conscience and Teaching			2	2				
Principles and Methods of Teaching I-II			2	2				
Teaching of Music I-II-III			2	2	3			
Turkish Culture				2				
Children Literature				2		2		
Science Lab*				**3**/2****				
Learning Psychology				2				
Environmental Science*				**2****				
Planning and Evaluation in Education I-II					4			
Teaching of Primary writing and reading					3			
Teaching of Mathematics I-II					3	3		
Teaching of Science I-II					**3**	**3**		
Teaching of Turkish						3		
Teaching of Social Science I-II					3	3		
Development and Techniques of Educational Materials					3			
Classroom Management						3		
An area of Course Book Critics							3	
Civics							2	
Drama in Primary Education							3	
An Elementary School Experience							3	
Turkish Literature in Republican Era							3	
Health and First Aid								2
Teaching in combined classrooms								2
Traffic Education								2
Guidance								3
Student Teacher/ School Experience I and II		5					5	5
Selective Course I-II-III-IV					2	2	2	2

* The science related courses before 1998 revision in an elementary teaching area of a four-year college in Turkey.
**Main Changes happened in the 1998 elementary education program science related courses and science teaching areas.
Note: The remaining courses had some minor changes but the name of courses and weekly credit hours not changed too much. That is why; those changes are not mentioned in this table.

Table 10. The name of courses and their credit hours of a four-year elementary teacher education department of College (Faculty) of Education, Usak University in 2006

Courses	Area	1st Year		2nd Year		3rd Year		4th Year	
		1st	2nd	3rd	4th	5th	6th	7th	8th
Principles of Atatürk and the History of Turkish Rev.	A	2	2						
General Geography	A		2						
Basic Mathematics I and II	A	2	2						
History of Civilization	A	2							
Turkish I (Written and Spoken)	GC	2	2						
Educational Psychology	TA		3						
Introduction to Education	TA	3							
Computer I and II,	GC	3	3						
Turkish History and Civilization	A		2						
Foreign Language	GC	3	3						
General Biology**	A	**2****							
General Chemistry**	A		**2****						
Physical Education and Sport Culture	A			2					
Teaching Methods and Principles	TA			3					
Sociology*	GC			2					
Introduction to Philosophy*	GC			2					
Turkish Language I (Syntax and Structure)	A			**2**	**2**				
Music	A			2					
Basic Physics **	A			**2****					
Environmental Education*	A			2					
Science and Technology Lab Applications I- II	**A**			**1****	**1****				
Geography and Geopolitics of Turkey	A				3				
Teaching Music	A				2				
Children Literature	A				2		2		
Art Culture and Teaching	A				2				
Physical Education and Game Teaching	A				2				
Fine Writing Techniques*	A				2				
Teaching Techniques and Material Design	TA				3				
Scientific Research Methods*	GC				2				
Teaching of Mathematics I-II	A					3	3		
Teaching of Science and Technology I-II	A					**3****	**3****		
Teaching of Reading and Writing	A					3			
Teaching of Civic / Social Science	A					3	3		
Drama in Primary Schools	A					3			
Assessment and Evaluation	TA					3			
Classroom Management	TA					2			
Teaching Turkish	A						3		
Early Childhood Education	A						2		
Public Service Applications**	GC						2		
School Experience I	A						3		
Art Teaching	A							2	
Religion Culture and Conscience Education	A							2	
Traffics and First Aid	A							2	
School Experience II	A							3	
Turkish Literature in Republican Era*	A							2	
Statistics*	GC							2	
Teaching in combined classrooms	A								2
Special Education	TA							3	
Guidance	TA							3	
History Turkish Education*	GC								2
Selective Course I*	TA								2
Student Teacher	TA								5
Selective Course I*	A								2
Turkish Education System and School Management	TA								2
Students with Learning Disabilities	GC								2
Total Weekly Credit Hours		19	21	18	21	20	19	19	17

A: Major Area Courses, GC: General Cultural Courses, TA: Teaching Area Courses (Total in four years is 154 credit/hours)
* Elective Courses suggested by Higher Education Council
** Science related courses in the latest revision of 2006 elementary education program.

In 1998, with a decision of THEC, the colleges of education in nationwide were reorganized and curriculum of elementary teacher education department became unique so that some minor differences between the colleges of education were ended in the elementary teacher programs (Yilman, 1999, p. 62). With this reorganization, some of courses were renamed, credit hours were changed, and some of them were added and dropped from the elementary teacher education program. These changes would be summarized as the following; the total number of credit hours is 156 credit hours, two new science courses were added as Environmental Science and Science Lab, the total number of credit hours of science courses including science teaching method courses is 19 credit hours and without including them, it is 13 credit hours. The ratio of credit hours of science courses including science teaching method courses are 12.1% (19/156). Almost, behalf of science courses there is approximately 2% increase. The other area courses had the minor changes but these changes seem to be not so important.

The latest revision in the elementary teacher education programs was made in 2006. According to the THEC, the need for this change is some problems arisen from the application of 1998 program and also some necessary updates had to be done after the eight years. The 2006 program could be seen in table 10.

However, the latest program change has shown that the weekly credit hours of science related courses were declined from 19 hours credit to 14 hours credit when it was compared with the 1998 program. This decline could be seen when the ratio and percentage of science related courses within the whole program (9.09%, 14 hours credit science related courses including science teaching courses in 154 hours credit in four years). It is difficult to explain the reason why the ratio of science related course declined in the latest program change in elementary teacher education program of Turkey while the basic scientific literacy of elementary teachers seems to be a common problem in Turkey.

Summary of the Historical Development of Elementary Teacher Education and the Percentage of Science Related Courses

Since 1868, elementary teacher education programs, curriculum, duration of educational time have been constantly changed, reorganized, revised and updated in Turkey. The number of total major revisions or updates of elementary teacher education programs is around 12. These changes are mostly based on the duration of education of elementary teacher schools from a two-year middle school level to a four-year higher education level with a bachelor of classroom (elementary) teaching degree. In table 11, the summary of percentages of science courses and the number of years of elementary teacher schools are given.

DISCUSSION AND CONCLUSION

Turkey has almost 135 years of elementary school teacher preparation history and experience from past to present as a formal and specially designed elementary teacher schools, institutes or colleges (faculties). In another word, approximately every 10 years there were changes based on the level of education as middle school, high school, two and four year colleges, the number of years of education, the name and weekly hours of courses.

The history of science, as a human endeavor and enterprise to explain the physical universe, could go back to the beginning of human kind. Historically, scientific activities have not had the same speed and progress throughout human history. Especially after the reform and renaissance movements in Europe, scientific studies got acceleration and many old and false scientific beliefs were changed by means of scientific studies conducted by the very well known scientists. Additionally, those scientific studies found the way of application in the new technological inventions. In the result, the world entered to the new era, called the industrial age. This era had enormous influences on humanity. In the agrarian societies, people mostly live in rural areas and show no need of education. However, with the following of industrial age, the number of people living in urban areas began to increase. Thus there was a need to educate people. People who lived in the industrial age had to be literate at least to survive and compete with the others. The way in which that was

Table 11. Percentages of science courses and the number of years of elementary teacher schools in Turkey

Year	Percentage	Duration (as a year)
1877	0	2*
1904	5.4	2*
1913	9.7	4*
1924	12.1	5*
1938	14-16	3**
1947	8.6	5*
1954	10.6	6*
1974	10.6	7*
1979	2.8	2***
1993	10	4***
1998	12.1	4***
2006	9.09	4***

* After Elementary School
** After Middle School,
*** After High School

possible was thorough education. Therefore, public school systems began to spread throughout many European countries around the second half of 18th century. However, it was difficult to find science or science related courses in early public school programs (Aikenhead, 2003). Similarly, in the Ottoman Empire under the western influence, the new public school systems beyond the traditional school systems began to be introduced in the second quarter of 1800s. Nevertheless, the school curricula of those western style schools at elementary and middle levels did not have any science or science related courses almost until at the end of 19th century (Table 1). Consequently, first western style teacher schools opened around the second half of 19th century. Those schools had none of science courses in their curricula. But towards the beginning of 20th century those elementary teacher schools put science courses on their curricula as one of their core courses.

The average percentage of science courses in the elementary teacher schools or college is around 9.69% with the exclusion of the first elementary teacher schools (Table 11). The highest percentage of science courses in the history of Turkish elementary teacher schools with the range of 12.1% and 16% belongs to the beginning of Republic area between 1923 and 1938 or the era of Ataturk. It should be thought that this would not be a coincident. Since one of the main aims of the Young Turkish Republic was to adapt the western values in every part of social life and made her citizens think scientifically, as mentioned previously. Additionally, it could be said that this would be an outcome of positivist influences of close friends of Ataturk as well as Ataturk himself at that time (Milliyet, a daily newspaper, www.milliyet.com.tr on the 29th of October, 2002). However, this trend seems to be not followed after the death of Ataturk. In the specially designed Village Institutes between 1940 and 1954 for the need of village elementary school teachers, the percentage of science courses was decreased because of many different courses from agriculture to health and child care courses (Table 6).

Until 1989, generally between 2.1 and 10% percent science courses are found in Turkish elementary teacher schools or institutes. Especially, after closure high school level elementary teacher schools, two-year elementary teacher institutes or junior colleges have the lowest percentage of science courses as 2.1% (Table 8). There should be different reasons, one of which would be that the students of two-year elementary teacher institutes or junior colleges already high school graduate so that they were assumed to have enough science course backgrounds and the other was the duration of education as two years. However, during this time period generally students placed to the two-year elementary teacher institutes or junior colleges had low achievement levels and poor science course backgrounds. In the result, the graduates of two-year elementary teacher institutes or junior colleges as elementary school teachers would be considered that they could not have enough science content knowledge or background. This consequence would influence their attitudes toward science and science teaching in elementary schools, as well.

In 1989 with a decision of THEC, the duration of years of elementary teacher was increased from two years to four years. This decision would be a turning point in the history of Turkish elementary teacher preparation because of the history of more than 100 years of elementary teacher schools becoming four-year college level schools in Turkey. Later with a revision, elementary teacher schools became a department under the four-year teacher (education) colleges instead of different four-year college level schools (in Turkey, four-year higher education institutes is classified into two parts as four-year higher schools and four-year colleges or faculties) in 1992. It was thought that with this revision elementary teacher schools got the real place where they deserved in Turkey. In spite of wide range of curriculum and courses in four-year elementary teacher departments under four-year teacher or education colleges, science courses were a crucial part of curriculum as the equivalent of 10% science course (Tables 10 and 11).

With the last changes happened in 1998 and 2006 teacher colleges in Turkey, every teacher's colleges' programs (the name of courses and academic structures of teacher colleges) and curricula (the content of courses) have become unique in the nation wide. Unfortunately, when the percentage of science courses of 1998 elementary teacher programs is compared with that of 2006, the percentage of science or science related courses has again declined from 12.1% to 9.09%. The contents of science courses given to elementary school teacher candidates mostly cover elementary science subjects, experiments, and teaching methods. It would be expected that a graduate from (the new elementary education program at) a four-year teacher college(s) should have enough science content and science teaching method knowledge as well as positive attitudes toward science and science teaching. The next step would be encouraging elementary school teachers or candidates to get master level education in Turkey.

Finally, since the opening of the first elementary teacher school in 1877, elementary teacher education in Turkey has showed change and progress but it seems that there is still no end to look for change.

REFERENCES

Aikenhead, G. S. (2003). Review of research on humanistic perspectives in science curricula, The paper presented at the European Science Education Research Association (ESERA) Conference, Noordwijkerhout, The Netherlands.

Akyuz, Y. (1993). Turk Egitim Tarihi [the History of Turkish Education], Istanbul.

Adıvar, A. (1991). Osmanlı Turklerinde Ilim [Science in the Ottoman Turks], Remzi Kitabevi, Istanbul. 5th Edition.

Atuf, N. (1931). Turkiye Maarif Tarihi [The History of Education of Turkey].

Bahadir, O. (1996). Osmanlilarda Bilim [Science in the Ottomans], Sarman Yayınevi, Istanbul.

Basaran, I. E. (1994). Turkiye Egitim Sistemi [The Educational System of Turkey], Ankara.

Berker, A. (1945). Turkiye'de Ilkogretim (1839-1908) [Primary Education in Turkey (1839-1908)], Milli Egitim Basimevi, Ankara.

Bilim, C. Y. (1998). Turkiye'de Cagdas Egitim Tarihi [The History of Contemporary Education in Turkey], Eskisehir.

Binbasioglu, C. (1992). Turkiye'de Egitim Bilimleri [Educational Sciences in Turkey], Istanbul.

Cetin, H. (2001). Egitimde Idealist Beklentiler Pragmatist Uygulamalar [Idealist Expectations Pragmatist Applications in Education] Ankara Universitesi Egitim Bilimleri Fakultesi Dergisi [Ankara University Journal of College of Educational Sciences], 27, 689-697.

Cumhuriyet Doneminde Egitim [Education in the Repuplican Era] (1983). Ministry of National Education Press, Istanbul.

Dag, O. and Oymen, H. (1974). Islam Egitim Tarihi [the History of Islamic Education], Ankara.

Dilaver, H. H. (1994). Turkiye'de Ogretmen Yetistirme ve Istihdam Sartlari [The Teacher Preparation and Employment Conditions in Turkey], Istanbul.

Ergun, M. (1996). II. Mesrutiyet Devrinde Egitim Hareketleri [Educational Movements in the Second Constitutional Era], Ankara.

Kafadar, O. (1997). Turk Egitim Dusuncesinde Batilasma [Westerinization in Turkish Educational Thought], Vadi Yayinlari, Ankara.

Kazamias, M. A. (1966). Education and the Quest for Modernity in Turkey, Chicago.

Kocer, H. A. (1967). Turkiye'de Ogretmen Yetistirme Politikasi [the Policy of Teacher Preparation in Turkey], Ankara.

Kodaman, B. (1991). Abdulhamid Devri Egitim Sistemi [Educational System in Abdulhamid Era], Turk Tarih Kurumu Basimevi, Ankara.

Ozodasik, M. (1999). Cumhuriyet Donemi Yeni Bir Nesil Yetistirme Calismalari 1923-1950 [The Studies of Preparation of a New Generation in Republic Era], Konya.

Ozturk, C. (1996). Ataturk Devri Ogretmen Politikasi [the Policy of Teacher in Ataturk Era], Ankara.

Turan, S. (2000). John Dewey's Report of 1924 and his Recommendations on the Turkish Educational System Revisited, History of Education, 29, 543-556.

Turan, O. (1969). Selcuklular Tarihi ve Turk Islam Medeniyeti [the History of Selcuks and Turkish-Islam Civilization], Istanbul.

Turan, S. (1995). Ogretmen Yetistirmede Anadolu Ogretmen Liselerinin Yeri ve Onemi [The Place and Importance of Anatolian Teacher High Schools in Teacher Preparation]. Edirne.

Yilman, M. (1999). Turkiye'de Ogretmen Egitimin Temelleri [The Foundations of Teacher Education in Turkey], Izmir.

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Research Framework on Mathematics Teacher Behaviour: Koehler and Grouws' Framework Revisited

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Educational reform centres on changing teacher behaviour, as it is teachers who filter through the curriculum to learners. Educational reform could therefore be viewed as reforming or changing teacher behaviour. This article investigates some of the factors influencing teachers' behaviour namely knowledge, attitude and views and beliefs. The complexity of research on teaching and teacher education is addressed by focusing on the elements of three factors as well as the relationship between these influencing factors. A research framework on teacher behaviour is presented, in an effort to expand the theoretical understanding of the factors influencing teacher behaviour and to guide future teacher education.

Keywords: Teacher Attitude, Teacher Behaviour, Teacher Beliefs, Teacher Knowledge

INTRODUCTION

Many countries are in the midst of educational reform, with the heart of this reform revolving around changes in the curriculum and teacher instructional behaviour (through teacher preparation). Teachers play a central role in bringing about the desired reform as it is the teacher who filters the curriculum through to learners (Jegede, Taplin & Chan, 2000). This implies that educational reform is implemented (in part) by changing teacher instructional behaviour. Adding to this, Jegede et al. (2000) note that for satisfactory and effective public education reform, it is essential that its most valuable human resource (i.e. teachers) must be comprehensively and adequately developed. In order to develop teachers and so change teacher instructional behaviour, it is essential to identify the factors influencing teacher behaviour but also the relationship between them. This article will endeavour to examine the factors influencing instructional behaviour, and in doing so, also suggest a (revised) research framework on teacher behaviour.

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THE COMPLEXITY OF RESEARCH ON TEACHING AND TEACHER BEHAVIOUR

In the 1980s Brophy (1986) noted that despite the remarkable progress made in research, classroom teaching (including research on school mathematics instruction) was in its infancy. Koehler and Grouws (1992) examined research on teaching from the perspective of complexity. Four levels of complexity and presentative models, that reflected the changes and progress made in research on teaching, were presented. The highest level (level 4) reflects current research, where research questions in teaching and learning are being approached from several perspectives, thus having a strong theoretical foundation (Koehler & Grouws, 1992). Koehler and Grouws' proposed model (1992) (see figure 1) postulates that outcomes of learning are based on a learner's own actions or behaviours, which are influenced by a) their beliefs about themselves as learners, b) their beliefs about the discipline of mathematics and c) what the teacher does or says within the classroom. Teachers' behaviour, according to the model, is influenced by the teacher's knowledge (of the content to be taught, how learners learn/understand that specific content and methods to teach that specific content) in addition to teachers' attitudes and beliefs about teaching and mathematics.

Teacher knowledge

Koehler and Grouws (1992) note that teacher behaviour is influenced by the teacher's understanding of the particular content and knowledge of how students might learn (National Research Council (NRC), 2001). This includes knowledge of how students think and learn (National Council of Teachers of Mathematics (NCTM), 2000; Ball, 1993) and, in particular, how this occurs within specific mathematics content (Fennema & Franke, 1992) but also examines sensitivity to the unique ways of learning, thinking about, and doing mathematics that the students have developed (NRC, 2001). Knowledge of how students acquire the knowledge of the mathematics content being addressed, as well as understanding the processes the students will use and the difficulties and successes likely to occur, form part of a teacher's knowledge of student learning (Fennema & Franke, 1992). Ball (1993) rephrases this kind of knowledge as "I must consider the mathematics in relation to the children and the children in relation to the mathematics".

Shulman (1986) presents a framework for discussion of teacher knowledge which postulates that teachers make decisions based on their knowledge. It has been presumed that teachers will develop this knowledge framework as a result of training and experience (Foss & Kleinsasser, 1996). The knowledge mathematics teachers need include knowledge of mathematics itself (subject content knowledge) (Muijs & Reynolds, 2002; Ball & Bass, 2000), and beyond pure subject matter knowledge the teacher needs to know how to teach mathematics (NRC, 2001). This includes knowledge of how to present mathematical topics and ideas (pedagogical content knowledge) and knowledge of mathematics curriculum materials and resources (curricular knowledge) (Shulman, 1986). Ball and Bass (2000) note that understanding and knowing subject matter knowledge is imperative in listening flexibly (hear what they are saying or where they might be heading) but also to be able to create suitable opportunities for learning (Ball, 2000). Ormrod and Cole (1996) report that an increase in knowledge of content could lead to changes in classroom practice that also reflect increased sophistication in pedagogical content knowledge. Knowledge of mathematics (content knowledge) is transformed by means of practical knowledge of mathematics teaching (both pedagogical and curricular) into representations for the classroom use of content knowledge (Ernest, 1989).

Pedagogical content knowledge (also termed pedagogical content knowing by Penso, 2002), can be described as practical knowledge of teaching (knowledge of how to teach that is specific to what is being taught) (Jegede *et al.*, 2000) by blending content and pedagogy (Ball *et al.*, 2001; Shulman, 1987). It includes knowledge of *approaches* to school mathematics topics; teachers' knowledge of teaching *procedures* such as effective strategies for planning, classroom practice, behaviour management techniques, classroom organizational procedures, and motivational techniques; different *ways of presenting* mathematics (Rowan, Correnti & Miller,

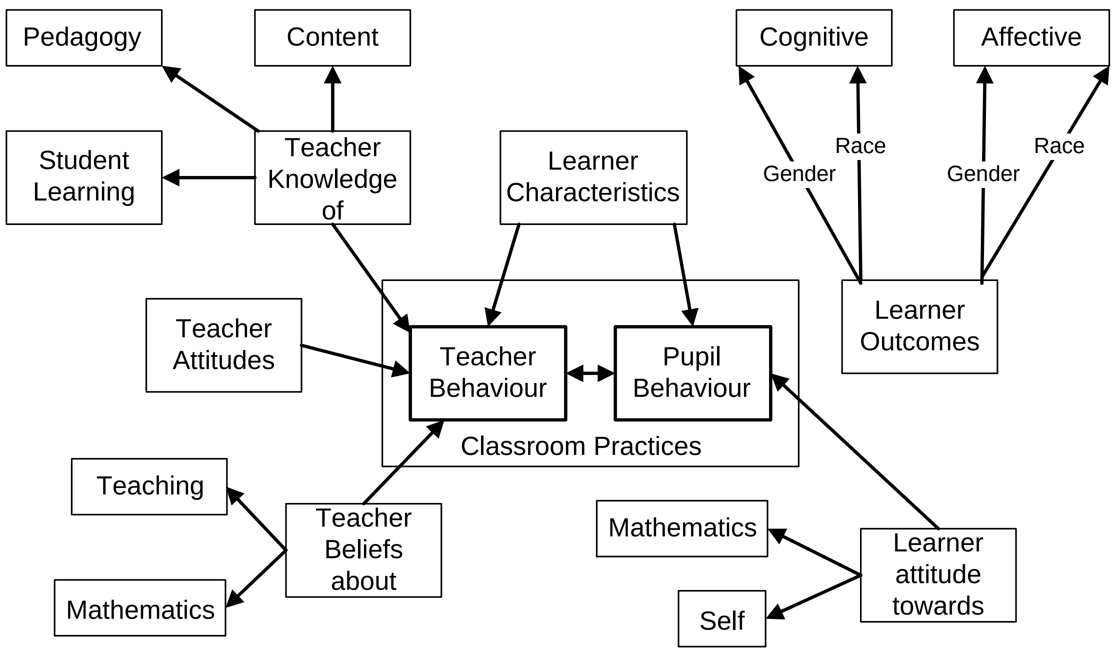

Figure 1. Level 4 research model (Koehler & Grouws, 1992, p.118)

2002; Shulman, 1986) through examples, illustrations, models and simulations (Geddis & Wood, 1997); knowledge of *students* (Penso, 2002) i.e. methods, conceptions, difficulties and common errors (Ball & Bass, 2000); knowledge of mathematical tasks, activities, test items (Fennema & Franke, 1992) and explanations (including alternative instructional methods (Rowan, Correnti & Miller, 2002). It is knowledge that a teacher uses to transform and represent knowledge either directly by the teacher, or by means of instructional media (Ernest, 1989) in order to make the subject matter accessible, comprehensible and compelling to a particular group of learners (Shulman, 1986). Ball and Bass (2000) summarize pedagogical content knowledge as a "unique subject specific body of pedagogical knowledge that highlights the close interweaving of subject matter and pedagogy in teaching". (p. 87)

Curricular knowledge includes knowledge of texts and schemes used to teach mathematics, their contents and ways to use them; school produced curriculum materials; other teaching resources and teaching apparatus; examinations, tests and syllabi (Turner-Bisset, 2001). Shulman (1987) changes the term of curricular knowledge to curriculum knowledge but still defines it as "tools of the trade" (p.8) which could be transcribed as knowledge of the materials and media ("tools") through which mathematics instruction is carried out and assessed (Turner-Bisset, 2001). Harland and Kinder (1997) indicate that this knowledge can have a positive and substantial influence on teachers' classroom practice. Cohen and Ball (2001) note the importance and value of teachers combining their knowledge of content, pedagogy, the selection of suitable curricula (NCTM, 2000) and use of resources.

Fennema and Franke (1992) note that there is a relationship between a teacher's knowledge and beliefs and according to Muijs and Reynolds (2002) these are related to student achievement. Both teacher's knowledge and beliefs have also been viewed as being context specific (Fennema & Franke, 1992). Thompson (1992) theorizes that because teachers treat their beliefs as knowledge, it is difficult to distinguish between knowledge and beliefs, with Manouchehri (1997) noting that teachers translate their knowledge of mathematics and pedagogy into practice through the filter of their beliefs. Turner-Bisset (2001) completes the triadic relationship between teacher knowledge, beliefs and attitude by noting that "one's beliefs about a subject can influence one's attitude towards it". (p.146)

Teacher beliefs

Teacher beliefs is the second factor in Koehler and Grouw's model (1992), as beliefs have a powerful impact on teaching (NRC, 2001) via teacher behaviour (Muijs & Reynolds, 2002; Schoenfeld, 2001) through such processes as the selection of content and emphasis, styles of teaching, and modes of learner learning (Ernest, 1989). Belief systems, according to Muijs and Reynolds (2002), are "dynamic and permeable mental structures, susceptible to change in light of experience" (p.4). A belief consists of the teacher's system of conceptions, values and ideology (Ernest, 1989) and is not consensual and is therefore held in varying degrees of conviction (Thompson, 1992). Studies of teachers' beliefs in mathematics education have investigated teachers' beliefs about the *nature of mathematics* (Ernest, 1989), as well as general conceptions of *mathematics teaching* (Cobb, Wood & Yackel, 1992).

Teachers' beliefs about the *nature of mathematics* are conscious or subconscious beliefs, concepts, meanings, rules, mental images, and preferences concerning the nature of mathematics as a whole (discipline of mathematics) (Ernest, 1989) that appear to affect teacher behaviour (Schoenfeld, 2001). These beliefs or conceptions form the bases of the teachers' own philosophy of mathematics, that teachers may hold consciously or implicitly (Thompson, 1992). Three philosophies/views of mathematics are distinguished due to their observed occurrence in mathematics teaching (Thompson, 1984) but also their prevalence in the academic study of the philosophy of mathematics. Ernest (1989) notes that teachers in practice might combine elements from these views. *Problem solving view*: This view is characterized by a dynamic problem-driven view of mathematics as a continually expanding field of human inquiry. Mathematics is not seen as a finished product, and its results remain open for revision (Ernest, 1989; Thompson, 1984). *Platonistic view*: Mathematics is viewed as a static/ fixed body (NRC, 2001) but a unified body of knowledge and procedures, consisting of interconnecting structures and truths which are to be discovered and not created (Ernest, 1989). *Instrumentalist view*: Mathematics is looked upon as being useful and consisting of an unrelated collection of facts, rules, skills (Ernest, 1989) and processes to be memorized (Leung, 1995).

The second belief system teachers hold is a mental model of *mathematics teaching* that Ernest (1989) views as the key determinant of how mathematics is taught. Kuhs and Ball (1986), as quoted by Thompson (1992, p.136), have identified at least four dominant and distinctive views teachers hold of how mathematics should be taught: *Learner focused*: Mathematics teaching in this view focuses on the learner's personal construction of mathematical knowledge (Manouchehri & Enderson, 2003) – typically underlay by a constructivist view of mathematics learning (Cobb & Bauserfeld, 1995). At the centre of this view is the learners' active involvement in constructing meaning from experiences by doing mathematics (De Jong & Brinkman, 1997) through exploration and formalizing ideas. This view is likely to be advocated by those who have a problem solving view of mathematics, who view mathematics as a dynamic discipline, dealing with self-generated ideas and involving methods of inquiry (Thompson, 1992). *Content focused with an emphasis on conceptual understanding*: Mathematics teaching in this view is driven by the content itself that emphasizes conceptual understanding (Thompson, 1992). This view of teaching would naturally follow the conception of the nature of mathematics that Ernest (1989) labels *Platonist*. In instruction, content is made the focus of classroom activity while emphasising students' understanding of ideas and processes. *Content focused with an emphasis on performance*: Student performance and mastery of mathematical rules and procedures, combined with stress on the use of exact, rigorous mathematical language (Leung, 1995) are emphasized in this view of teaching mathematics. This view of teaching would follow naturally from the instrumentalist view (Ernest, 1989) of the nature of mathematics. This view has the following central premises: a) rules are the basic building blocks of all mathematical knowledge (as mathematics is perceived as a fixed body of knowledge) thus making all mathematical behaviour rule-governed (Leung, 1995); b) knowledge of mathematics is demonstrated by correctly answering and solving problems using the learned rules; c) computational procedures should be "automatized"; d) it is not necessary to understand the source or reason for student errors as further instruction will result in appropriate learning (Kuhs and Ball 1986 as quoted by Thompson, 1992, p.136). *Classroom focused with mathematical teaching based on knowledge about effective classrooms.* Central to this view is the notion that classroom activity must be well structured and efficiently organized according to effective teacher behaviours identified in process-product studies of teaching effectiveness (Thompson, 1992).

Teacher attitudes

Koehler and Grouws (1992) note that teachers' behaviour is not only influenced by their beliefs but also by their attitudes towards mathematics and the teaching of mathematics. Attitudes are defined as internal beliefs that influence personal actions (Schunk, 1996). Gagnè believes (according to Schunk, 1996, p.392) that attitude is learned indirectly through one's experience and exposures.

Teachers' *attitude towards mathematics* itself includes liking (Quinn, 1998), enjoyment and interest in mathematics, teacher's confidence in his or her own mathematical abilities: the teacher's mathematical self-concept, and the teacher's valuing of mathematics (Ernest, 1989). A teacher's self-concept is formed through experiences and interpretations of the environment and depends heavily on reinforcement and evaluations by significant others (Schunk, 1996).

Attitudes to mathematics and its teaching are important contributors to a teacher's make-up and approach, because of the effect they can have on a child's attitude to mathematics and its learning but ultimately on student achievement in mathematics (Ernest, 1989). Teachers' attitude to the *teaching of mathematics* include liking, enjoyment and enthusiasm for the teaching of mathematics, and confidence in the teacher's own mathematics teaching abilities (Ernest, 1989).

Shulman (1987) mentions that teachers should possess knowledge of student characteristics, with Koehler and Grouws (1992) indicating that student characteristics have an influence on the teacher's behaviour, but neither defined which characteristics and how these characteristics influence the teacher's behaviour. The framework put forth for examination and discussion centres on factors influencing teacher behaviour, while attempting to incorporate student characteristics as well as teachers' beliefs on the learning of mathematics. The interactive and dynamic nature of the components as well as how it influences teacher behaviour will be addressed.

A RESEARCH FRAMEWORK ON TEACHER BEHAVIOUR

The proposed model (see figure 2) includes all three factors noted by Koehler and Grouws (1992), namely teacher knowledge, teacher beliefs and teacher attitude. Some additions were made to the model with respect to all three factors. Each addition and/or change will briefly be discussed with some attention given to the interactive nature of the added components.

Teacher knowledge

The author is in agreement with Fennema and Franke (1992) that teacher knowledge is a large, integrated, functioning system and is an important indicator of overall teacher effectiveness (Kanes & Nisbet, 1996). Four components distinguished in teachers' knowledge consist of teachers' knowledge of student learning, subject content knowledge, pedagogical knowledge and *curriculum knowledge*. Curriculum knowledge is explicitly added to the model as knowledge of the subject content (concepts, procedures) and knowledge of different ways of presenting the content (pedagogical knowledge) does not guarantee knowledge of different and effective teaching and assessment resources such as computer software. A teacher with knowledge of various teaching tools may choose to apply a specific tool and combine it with an appropriate teaching style which could lead to learning becoming more effective. For example, a teacher being aware of a specific computer software programme, could design his/her own examples and students could explore their own choices (Kong & Kwok, 1999) to discover theories while constructing their own knowledge, whereas a teacher using only the traditional pen and paper method could be tempted to "transmit" the knowledge to learners. In short, the greater the knowledge of different teaching resources, the more "freedom" a teacher has in the chosen teaching approach. Ernest (1989) notes that this knowledge (curriculum knowledge) is vital to the planning and has a powerful influence on the carrying out of mathematics teaching (Cohen & Ball, 2001) as it is situated in context (Turner-Bisset, 2001). By adding curriculum knowledge, rightful recognition is given to the triadic relationship between subject content knowledge, pedagogical knowledge and curriculum knowledge (as first noted by Shulman, 1986).

Teacher beliefs

Two factors (beliefs about the learning of mathematics and beliefs about students as learners) were added to the original two factors that consisted of teachers' beliefs about mathematics and the teaching of mathematics. Attention will be given only to the two added factors.

Beliefs about the learning of mathematics

Teachers' belief system of the learning of mathematics consists of the teachers' view of the learning process, behaviours and mental activities on the part of the learner, and appropriate and prototypical learning activities, in particular the aims, expectations, conceptions and images of learning activities and the processes of learning mathematics in general (Ernest, 1989). Two key constructs on the learning of mathematics are as follows: viewing learning as the active construction of knowledge as a meaningful connected whole, versus a passive reception of knowledge and the development of autonomy and the learner's own interest in mathematics versus a view of the learner as submissive and compliant. The teacher's model of learning mathematics is a vital factor in the learner's experience of learning mathematics as it influences both the cognitive and affective outcomes of learning experience (Ernest, 1989).

Students as learners

Teachers' beliefs about their students as learners include beliefs about differences in individuals or groups of learners regarding the learners' talent for mathematics and learners' intellectual abilities to successfully learn mathematics. Leung (1995) reports that educational practices of teachers concerned with individual differences amongst students differed significantly from

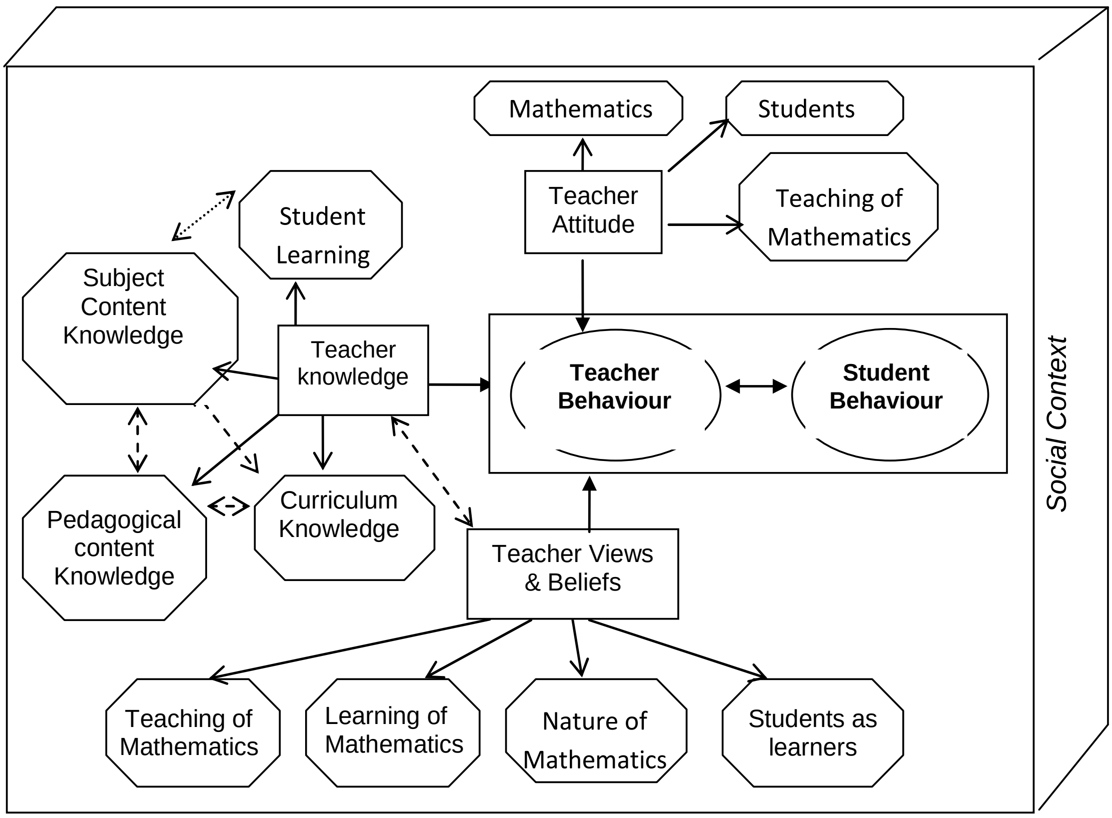

Figure 2. Research framework on teacher behaviour

those of teachers who emphasized conformity. These teachers adopted individual learning programmes in order for students to proceed at different paces. In addition, Penso (2002) notes in her study that prospective teachers believed that most of the learning difficulties were due to the learner's characteristics. Teachers' beliefs about learners could be as varied as believing that some learners are born good learners while others are stuck with a limited ability. Furthermore teachers could believe that some learners have natural talents for mathematics while others do not, so working hard at a problem will only pay off for "smart" learners. If teachers rely on the belief that learners must possess innate knowledge or have a certain type of mind in order to understand mathematics, it could lead to teachers believing that it relinquishes them from their responsibility for applying methods to teach challenging mathematics (Foss & Kleinsasser, 1996).

The relationship between the four factors can be described as follows: The teacher's view of the nature of mathematics provides a basis and is likely to correspond to a teacher's mental models of the teaching and learning of mathematics (Ernest, 1989) which in turn could be influenced by a teacher's beliefs about learners. For example, the problem-solving view of mathematics corresponds to the view that the teacher is a facilitator, the learner is autonomous and learning is the active construction of understanding through problem solving (Ernest, 1989). So too will the view of mathematics as a Platonist unified body of knowledge correspond to a view of the teacher as explainer, and learning as a reception of knowledge, although with an emphasis on the learner constructing a meaningful body of knowledge. The instrumental view of mathematics is likely to be associated with a transmission model of teaching, where the strict following of a text or scheme is advocated (Ernest, 1989). Each of these views (as demonstrated by teacher behaviour) can be influenced by a teacher's belief about the learner's talent, capacity or ability to learn mathematics successfully. If a teacher, for example, believes the learner does not have the (intellectual) ability or talent to learn mathematics in a problem solving manner (by actively constructing own knowledge), the teacher may be tempted to teach mathematics as a set of rules and procedures (instrumentalist view). Learning would then be deemed successful if learners solve problems using the learned rules or procedures (content focused with an emphasis on performance) and present solutions in a fixed format (Leung, 1995).

Teacher attitude

Teachers' attitude is the third factor noted by Koehler and Grouws (1992) and consists of a teacher's attitude towards mathematics and the teaching of mathematics, with the addition of a teacher's attitude towards students. The teacher's attitude to mathematics (for example enthusiasm and confidence) itself may affect the teacher's attitude to the teaching of mathematics, which in turn has a powerful impact on the atmosphere of the mathematics classroom (Ernest, 1989).

Attitude towards students

Attitudes teachers hold regarding students could be attitudes towards individual learners, groups or classes of learners. This could include liking (affection towards learners), enthusiasm to teach these specific learner(s) and familiarity with the culture (e.g. European versus Asian) (Leung, 1995). Teachers are more likely to exhibit more enthusiasm in preparation and presentation of lessons when they are affectionate towards learners than when they are apathetic or indifferent towards these students. This attitude towards student(s) could be formed due to characteristics exhibited by a student or a group of students (such as low socio-economic status, poor discipline, physical appearance or special educational needs e.g. speech difficulties (Dada & Alant, 2002) that teachers personally find "acceptable or unacceptable" or "attractive or repulsive". Penso (2002) reports that prospective teachers explained learning difficulties by focussing on student characteristics, it being convenient "to blame" students, with such remarks as "if only (the students) would listen, they would understand". (p. 34)

Social context

Fennema and Franke (1992) note that teacher's knowledge and beliefs are held within specific contexts as a result of the dynamic interaction of the factors involved in the learning process (Penso, 2002). It could be suggested that due to the relationship between a teacher's knowledge, beliefs and attitude, the teacher's behaviour, as influenced and defined by knowledge, beliefs and attitude, is context specific. Context can vary enormously (Turner-Bisset, 2001) and within a given context, a teacher's knowledge combines with his/her attitude and beliefs about teaching and learning, mathematics and students to create a unique setting that drives classroom behaviour. The teachers' attitude, beliefs and views as well as their knowledge as demonstrated by instructional behaviour are subject to the constraints and contingencies of the social and school context (Fennema & Franke, 1992). Within a given context, teachers' knowledge interacts with their views and beliefs and combines with their attitude to drive classroom behaviour (Fennema & Franke, 1992).

CONCLUSION

Reflecting on the completeness of the presented framework, the author is open to the possibility that other components could be added in future. An aspect that the framework did not include was a possible language differences between the teacher and students (e.g. the teacher teaching or students receiving instruction in their second language). This aspect as well as the applicability of this framework in related subjects (e.g. science) and in other disciplines (e.g. Language instruction) could be areas for future research. This framework could also be applied to the in-service and pre-service training of mathematics teachers to investigate the strength of the interrelatedness of the components.

If educational reform is to be successful, colleges and universities may need to evaluate the suitability of the mathematical topics of courses targeted at mathematics teachers (Kanes & Nisbet, 1996). These courses should ideally encompass elements to improve knowledge (subject content, pedagogy (Quinn, 1998) and curriculum knowledge) but also make teachers and prospective teachers aware of their own beliefs and attitudes as well as the role and impact of their beliefs and attitudes towards mathematics, learner characteristics and the teaching and learning of mathematics within a specific social context. Changes are required in how teachers learn and in the opportunities to learn with course content focussing more on the synergy between knowledge, attitude and beliefs.

REFERENCES

Ball, D.L. (1993). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics. *The Elementary School Journal*, *93*(4), 373-397.

Ball, D.L. (2000). Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. *Journal of Teacher Education*, *51*(3), 241-247.

Ball, D.L., & Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), *Multiple Perspectives on Mathematics of Teaching and Learning.* (pp. 83-104). Westport, Conn.: Ablex Publishing.

Brophy, J. (1986). Teaching and learning mathematics: Where research should be going. *Journal for Research in Mathematics Education, 17*(5), 323-346.

Cobb, P., Wood, T., & Yackel, E. (1992). A constructivist approach to second grade mathematics. In E. Von Glasersfeld (Ed.) *Radical Constructivism in Mathematics Education*. Dordrecht: Kluwer.

Cobb, P., & Bauserfeld, H. (Eds.). (1995). *The emergence of mathematical meaning: Interaction in classroom cultures.* Hillsdale, NJ: Erlbaum.

Cohen, D. K., & Ball, D. L. (2001). Making change: Instruction and its improvement. *Phi Delta Kappan, 83*(1), 73-77.

Dada, S., & Alant, E. (2002). A comparative study of the attitudes of teachers at special and educationally inclusive schools towards learners with little or no functional speech using communication devices. *South African Journal of Education, 22*(3), 213-218.

De Jong, O., & Brinkman, F. (1997). Teacher thinking and conceptual change in science and mathematics education. *European Journal of Teacher Education*, *20*(2), 121-124.

Ernest, P. (1989). The knowledge, beliefs and attitudes of the mathematics teacher: A model. *Journal of Education for Teaching*, *15*(1), 13-33.

Fennema, E., & Franke, M. L. (1992). Teachers' knowledge and its impact. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics.* (pp. 147-164). New York: Macmillan.

Foss, D. H., & Kleinsasser, R. C. (1996). Preservice elementary teachers' view of pedagogical and mathematical content knowledge. *Teaching and Teacher Education*, *12*(4), 429-442.

Geddis, A. N., & Wood, E. (1997). Transforming subject matter and managing dilemmas: A case study in teacher education. *Teaching and Teacher Education*, *13*(6), 611-626.

Harland, J., & Kinder, K. (1997). Teachers' continuing professional development: Framing a model of outcomes. *British Journal of In-Service Education*, *23*(1), 71-84.

Jegede, O., Taplin, M., & Chan, S. (2000). Trainee teachers' perception of their knowledge about expert teaching. *Educational Research*, *42*(3), 287-308.

Kanes, C., & Nisbet, S. (1996). Mathematics-teachers' knowledge bases: Implications for teacher education. *Asia-Pacific Journal of Teacher Education*, *24*(2), 159.

Koehler, M. S., & Grouws, D. A. (1992). Mathematics teaching practices and their effects. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics.* (pp. 115-125). New York: Macmillan.

Kong, S., & Kwok, L. (1999). An intensive teaching and learning environment for graph sketching. *Computers and Education, 32*, 1-17.

Leung, F. K. S. (1995). The mathematics classroom in Beijing, Hong Kong and London. *Educational Studies in Mathematics*, *29*, 297-325.

Manouchehri, A. (1997). School mathematics reform: Implications for mathematics teacher preparation. *Journal of Teacher Education*, *48*(3), 197.

Manouchehri, A., & Enderson, M. C. (2003). The utility of case study methodology in mathematics teacher preparation. *Teacher Education Quarterly*, *30*(1), 113-135.

Muijs, D., & Reynolds, D. (2002). Teachers' beliefs and behaviours: What really matters? *Journal of Classroom Interaction*, *37*(2), 3-15.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council. (2001). *Adding it up: helping children learn mathematics*. Washington, DC: National Academy Press.

Ormrod, J. E., & Cole, D. B. (1996). Teaching content knowledge and pedagogical content knowledge: A model from geography education. *Journal of Teacher Education, 47*(1), 37.

Penso, S. (2002). Pedagogical content knowledge: How do student teachers identify and describe the causes of their pupils learning difficulties. *Asia-Pacific Journal of Teacher Education*, *30*(1), 25-37.

Quinn, R. J. (1998). Effects of mathematics methods courses on the mathematical attitudes and content knowledge of preservice teachers. *Journal of Educational Research*, *91*(2), 108.

Rowan, B., Correnti, R., & Miller, R. J. (2002). What large-scale, survey research tells us about teacher effects on student achievement: Insights from the "Prospects" study of elementary schools. *Teachers College Record, 104*(8), 1525-1567.

Schoenfeld, A. H. (2001). Mathematics education in the twentieth century. In L. Corno (Ed.), *Education across a century: The centennial volume*. (pp. 239-278). Chicago, Ill.: National Society for the Study of Education, University of Chicago Press.

Schunk, D. H. (1996). *Learning theories: An educational perspective* (2nd ed.). Englewood Cliffs, N.J.: Merrill.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-22.

Thompson, A.G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. *Educational Studies in Mathematics*, *15,* 105-127.

Thompson, A.G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics*. (pp. 147-164). New York: Macmillan.

Turner-Bisset, R. (2001). *Expert teaching: Knowledge and pedagogy to lead the profession.* London: David Fulton.

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An Overview of Conceptual Change Theories

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Conceptual change researchers have made significant progress on two prominent but competing theoretical perspectives regarding knowledge structure coherence. These perspectives can be broadly characterized as (1) knowledge-as-theory perspectives and (2) knowledge-as-elements perspectives. These perspectives can be briefly summarized in terms of the following questions. Is a student's knowledge most accurately represented as a coherent unified framework of theory-like character (e.g., Carey, 1999; Chi, 2005; Ioannides & Vosniadou, 2002; Wellman & Gelman, 1992)? Or is a student's knowledge more aptly considered as an ecology of quasi-independent elements (e.g., Clark, 2006; diSessa, Gillespie, & Esterly, 2004; Harrison, Grayson, & Treagust, 1999; Linn, Eylon, & Davis, 2004)? In this review, we clarify these two theoretical perspectives and discuss the educational implications of each. This debate is important because these perspectives implicate radically different pathways for curricular design to help students reorganize their understandings. Historically, the research literature has predominantly supported knowledge-as-theory perspectives. After outlining both perspectives, this paper discusses arguments and educational implications that potentially favor the adoption of knowledge-as-elements perspectives

Keywords: Conceptual Change, Conceptual Ecology, Knowledge Structure Coherence

INTRODUCTION

Fundamental research among science educators and cognitive scientists focuses on how people learn science and how people apply this knowledge in their daily lives. Theoretical perspectives on knowledge structure coherence are fundamental to much of this research. Researchers have made significant progress on two prominent but competing broad theoretical perspectives regarding knowledge structure coherence: (1) knowledge-as-theory perspectives and (2) knowledge-as-elements perspectives. Essentially, is a student's knowledge most accurately represented as a coherent unified framework of theory-like character (e.g., Carey, 1999; Chi, 2005; Ioannides & Vosniadou, 2002; Wellman & Gelman, 1992)? Or is a student's knowledge more aptly considered as an ecology of quasi-independent elements (e.g., Clark, 2006; diSessa, Gillespie, & Esterly, 2004; Harrison, Grayson, & Treagust, 1999; Linn, Eylon, & Davis, 2004)? Recently, diSessa (2006) organized an excellent review of the historical development in the conceptual change literature along this division. In our review, we clarify the theoretical perspectives and discuss the educational implications of each.

The descriptions of the two theoretical positions presented above are simplifications of the actual perspectives, which are considerably more nuanced as a result of substantial research and ongoing debate amongst their respective proponents. Proponents of knowledge-as-theory perspectives, for example, do not argue that students' knowledge is "theory-like" in the same fashion as the knowledge of scientists (e.g., including the scientists' awareness of the nature of their

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theories or the scientists ability to engage in hypothesis testing with regard to their theories). These proponents do argue, however, for an overarching hierarchical conceptual structure with theory-like properties that constrains a student's interpretation of subordinate models and ideas. Similarly, the knowledge-as-elements perspectives should not be incorrectly caricatured as the random interaction of independent elements. Rather, elements interact with each other in an emergent manner where the combinatorial complexity of the system constrains students' interpretations of phenomenon. While the researchers in each camp also vary along other important issues (e.g., conceptual grain-size, ages of students, methods, and scientific content areas) this debate remains highly visible and contested. The importance of the debate is critical because these models implicate radically different pathways for curricular design to help students reorganize their understandings.

KNOWLEDGE-AS-THEORY PERSPECTIVES

Piagetian learning theory has influenced many researchers of knowledge-as-theory perspectives. Studies of the philosophy and history of science have also influenced many of these researchers. To explain a conceptual shift, proponents of knowledge-as-theory perspectives often present analogies between Piaget's concepts of assimilation and accommodation and Kuhn's (1962) concepts of normal science and scientific revolution (e.g., Carey, 1985, 1999; Wiser & Carey, 1983). While some of these researchers have explained conceptual change in terms of framework theories and mental models (e.g., Vosniadou, 1994; Vosniadou & Brewer, 1992), others have focused on higher level ontological shifts (Chi, 1992). The following section provides an overview of the core conceptual change research related to knowledge-as-theory perspectives.

Research on Conceptual Change by Assimilation and Accommodation

One of the most prominent conceptual change theories, which correspond to Kuhn's notion of a paradigm shift or Piaget's notion of accommodation, was defined by Posner, Strike, Hewson, & Gertzog (1982). They proposed that if a learner's current conception is functional and if the learner can solve problems within the existing conceptual schema, then the learner does not feel a need to change the current conception. Even when the current conception does not successfully solve some problems, the learner may make only moderate changes to his or her conceptions. This is called "conceptual capture" (Hewson, 1981) or "weak restructuring" (Carey, 1985). In such cases, the assimilations go on without any need for accommodation. It is believed that the learner must be dissatisfied with an initial conception in order to abandon it and accept a scientific conception for successful conceptual change. This more radical change is called "conceptual exchange" (Hewson, 1981) or "radical restructuring" (Carey, 1985). According to Posner et al. (1982), the scientific conception must also be intelligible, plausible, and fruitful for successful conceptual change to occur. Intelligible means that the new conception must be clear enough to make sense to the learner. Plausible means the new conception must be seen as plausibly true. Fruitful means the new conception must appear potentially productive to the learner for solving current problems. Posner et al.'s perspective assumes that these cognitive conditions should be met during the learning process for a successful conceptual change. The major goal is to create a cognitive conflict to make a learner dissatisfied with his or her existing conception. Then, the learner may accept a normative view as intelligible, plausible, and fruitful. This view has been very influential theory to determine a learner's specific conceptions that result from the interaction between beliefs and knowledge of the learner.

Posner et al. (1982) embed their explanation of conceptual change within a conceptual ecology perspective. According to Posner et al., a learner's conceptual ecology consists of their conceptions and ideas rooted in their epistemological beliefs. This conceptual ecology perspective has proven very influential. Even though Posner et al.'s primary mechanism for conceptual change has been rejected by many proponents of knowledge-as-elements perspectives, many knowledge-as-elements (as well as many knowledge-as-theory proponents) have adopted this larger conceptual ecology architecture into their perspectives. From a conceptual ecology perspective, the constituent ideas, ontological categories, and epistemological beliefs highly influence a learner's interactions with new ideas and problems. Misconceptions are therefore not only inaccurate beliefs; misconceptions organize and constrain learning in a manner similar to paradigms in science. In other words, prior conceptions are highly resistant to change because concepts are not independent from the cognitive artifacts within a learners' conceptual ecology. Some concepts are attached to others and they generate thoughts and perceptions. Because of this web-based relationship between concepts, a revision to a concept requires revisions to others. Thus, Strike and Posner (1992) advocate that:

> This theory of conceptual change is embedded in a set of epistemological assumptions that are far more generalizable than our application to misconceptions has exploited. These epistemological assumptions suggest that the basic problem of understanding

> cognitive development is to understand how the components of an individual's conceptual ecology interact and develop and how the conceptual ecology interacts with experience (p. 155-156).

Research on the Incommensurability of Adults' and Children's Concepts

Another area of research that supports knowledge-as-theory perspectives focuses on the notion that adults' and children's concepts are each coherent but incommensurable with one another (Carey, 1985). In other words, people maintain coherent theory-like understandings of concepts. Change between concepts can be achieved, according to Carey (1991), through three processes: replacement, differentiation, and coalescence. In replacement, one concept displaces another concept, where the two concepts are fundamentally different; it is an overwrite procedure. Differentiation is another process in which the initial concept splits into two or more new concepts such as dog differentiated into the more specific terms collie and terrier. Coalescence is the opposite process of differentiation; Coalescence involves two or more original concepts coalescing into a single concept, such as collie and terrier into the more general category of dog.

Research on Gradual Transformations of Naïve Theories

While the term "revolutionary" evokes the idea of instantaneous change, recent research supports gradual transformations in conceptual change. Carey (1999) proposes such a view in terms of children's naïve biological theories. She proposes that conceptual change cannot be thought of as "global restructuring" as described by Piaget. Rather, conceptual change should be thought of as "domain specific restructurings." According to this view, children restructure their naïve theory structures by increasing their knowledge in a specific domain. As children are exposed to new experiences and instruction, they gradually replace their theory-like conceptual structures with scientifically correct conceptual structures. These restructurings result from the child's increased knowledge of a domain, social interactions, and a variety of disequilibrating influences, partially resulting from the development of the logical structures of the child.

According to Carey, concepts and beliefs are the two primary components of intuitive knowledge. Beliefs are the relational pieces that connect concepts. For example, "people are animals" refers to two different concepts, people and animals. She argues that while changes in relations between the concepts are relatively easy, changes in the concepts are thorny processes because intuitive theories constrain the concepts in which beliefs are formed. Therefore, conceptual change is a gradual process that occurs at the level of individual concepts.

Hatano and Inagaki (1996) focus on naïve theories of children within biological concepts. Their view is consistent with that of Carey (1999), that young children, before being taught in school, possess a fairly well-developed body of biological knowledge that enables them to make consistent predictions and explanations regarding biological phenomena. Naïve knowledge is constructed through daily experiences at early ages and formal biology is constructed from naïve biology through the restructuring of it.

Research on Mental Models, Framework Theories, and Ontological Shifts

Several researchers focus on conceptual change processes in terms of mental models (e.g., Ioannides & Vosniadou, 2002; Linder, 1993; McCloskey, 1983; Smith, Blakeslee, & Anderson, 1993; Vosniadou, 1994; Vosniadou & Brewer, 1992). Vosniadou and Ioannides (1998), for example, explore spontaneous changes and instruction-based changes at the mental model level. Spontaneous change is change that occurs in young children without specific instruction through the enrichment of observations and other kinds of learning, such as language learning. This position is very similar to Carey's (1999) argument that even very young children develop theories and make predictions about phenomena. Their causal explanations reflect ontological commitments that are subject to revision and radical change. Instruction-based change focuses on the evolution of children's mental models through the introduction of formal scientific instruction. Instruction leads children to construct synthetic mental models that are still inconsistent with the scientific theory. However, these synthetic mental models imply that students begin to synthesize the scientific theory with their initial theory. They make changes in their beliefs based on the instruction of an authority figure, but they still lack the full scientific theory due to their ontological and epistemological commitments.

This development of synthetic models reveals that ontological commitments must be changed in order to fully restructure a student's framework theory. Thus, akin to Carey's opinion, Vosniadou claims that children's generation of scientific models is constrained by their framework theories. For example, elementary school students in Vosniadou and Brewer's (1992) sample consistently constructed the Earth models in disc or rectangular flat shape based on their everyday experience. Vosniadou and Brewer called these "initial" models because they are not affected by the scientific model of the Earth. However, older students constructed some synthetic Earth models (Dual Earth, hollow sphere, and flattened sphere) influenced by the spherical shape of the Earth from instruction. Vosniadou and Brewer suggested that in the formation of these mental models, students' beliefs about the Earth based on their observations and cultural influences are constrained by a naïve framework of presuppositions (Vosniadou, 1994).

> Two of the presuppositions of the framework theory are particularly important because they have the potential to explain the formation of the initial and synthetic models of the Earth children construct. They are: (a) the presupposition that space is organized in terms of the directions of up and down with respect to a flat ground, and (b) the presupposition that unsupported objects fall in a downward direction. The assumption that children are operating under the constraints of these two presuppositions can explain the formation of the initial and synthetic models of the Earth obtained in our sample (p. 55).

According to Vosniadou (1994), students generate misconceptions or synthetic mental models that combine aspects of the scientific model with their initial models within the constraints of their framework theories. The presuppositions of the framework theory need to be revised and eventually replaced to allow for the scientific model.

The framework theory perspective is consistent with Chi's (1992) argument that conceptual change requires an ontological shift. Chi (1992) believes that the conceptual change process is hard because either (a) the student assigns the concept to a different ontological category from the scientific one or (b) the student lacks an appropriate category to which the concept could be assigned. If students become aware of their ontological commitments, they can then become aware of how the scientific theory does not fit with their existing knowledge structure. In turn, they can assign the concept into a correct category by revising their ontological commitments, categories, and presuppositions.

Researchers of these perspectives emphasize that radical changes like these do not take place suddenly. Rather, they involve gradual and time-consuming processes because the student must revise and restructure an entire network of beliefs and presuppositions. While Chi's argument focuses specifically on changing ontological categories, Vosniadou and Ioannides (1998) suggest that ontological change is only one of the changes required in the process of changing theories. As students slowly revise their initial conceptual system over time by adding the elements of scientific explanation, students should be guided through instruction to create larger theoretical constructions with greater explanatory power.

Summary and Synthesis of Knowledge-as-Theory Perspectives

In summary, knowledge-as-theory perspectives hypothesize theory-like naïve knowledge structures. This theory-like knowledge is hypothesized to involve coherent structures grounded in persistent ontological and epistemological commitments. Because novices unconsciously develop these coherent structures through collections of daily experiences, their "theories" are not available for hypothesis testing in a manner similar to scientists' theories. However, novices' alternative conceptions do constrain future learning and allow novices to make consistent predictions across conceptual domains. Knowledge-as-theory perspectives hypothesize revolutionary change in knowledge structures through various mechanisms. Some researchers frame their conceptual change theories in terms of Piaget's notion of assimilation and accommodation or Kuhn's notion of a paradigm shift. Some researchers explain conceptual change in terms of the notion of incommensurability demonstrating the distinction between the roots of the concepts. Other researchers propose ontological shifts and the evolution of mental models. Although these knowledge-as-theory perspectives have developed in different domains, such as force and motion (McCloskey, 1983), astronomy (Vosniadou & Brewer, 1992), biology (Carey, 1999), and heat and temperature (Wiser & Carey, 1983), they all assert that learners at any given time maintain a small number of well-developed coherent naïve theories based on their everyday experiences and that these theories have explanatory power to make consistent predictions and explanations across significant domains.

KNOWLEDGE-AS-ELEMENTS PERSPECTIVES

While the aforementioned knowledge-as-theory perspectives on conceptual change process have wide support within the science education community, several researchers have proposed opposing perspectives that characterize students' understanding in terms of collections of multiple quasi-independent elements (e.g., Brown, 1995; Clark, 2006; diSessa, 1988, 1993; Hunt & Minstrell, 1994; Linn, Eylon, & Davis, 2004). Anderson (1993) and Thagard (1992) provide relatively mechanical/mathematical examples of this perspective. Clark (2006), diSessa, Gillespie, and Esterly (2004), Hunt and Minstrell (1994), and Linn, Eylon, and Davis (2004) maintain more organic perspectives that focus on collections of elements including, but not limited to, phenomenological primitives, facts, facets, narratives, concepts, and mental models at various stages of development and sophistication. diSessa focuses more on the nature of the elements, Clark focuses on longitudinal processes of change, Minstrell focuses on the facets student use in the classroom, and Linn focuses on the process through which students reorganize, revise, and connect these elements. Learning occurs through a process of restructuring and reorganizing these ideas.

diSessa's perspective is the most well known of the knowledge-as-elements perspectives. diSessa (1993) proposes that the knowledge structures of novices consist primarily of unstructured collections of many simple elements that he calls p-prims (phenomenological primitives). P-prims are developed through a sense-of-mechanism that reflects our interactions with the physical world such as pushing, pulling, throwing, and holding. The learner merely assumes that "something happens because that's the way things are" (diSessa, 1993, p. 112). These implicit presuppositions influence learners' reasoning when they interpret the world (Ueno, 1993). P-prims do not have the status of a theory because they are not produced or activated under a highly organized system like the framework theories proposed by knowledge-as-theory perspectives. These p-prims are generated from a learner's experiences, observations, and abstractions of phenomena. Individual p-prims are loosely connected into larger conceptual networks. diSessa describes cuing priority, reliability priority, and structured priorities to propose how those p-prims are recognized and activated according to context.

Some recent empirical evidence supports diSessa's argument. Southerland, Abrams, Cummins, and Anzelmod (2001) explored the nature of students' biological knowledge structure. They concluded that p-prims have more explanatory power than conceptual frameworks theory regarding the shifting nature of students' conceptions of biological phenomena. Clark's (2006) longitudinal study in thermodynamics strongly suggests that students' understanding of heat and temperature can be explained through a related elemental perspective. In the domain of force, Özdemir and Clark (in preparation) investigated knowledge structures of students from kindergarten to high school and found that students' knowledge structures were best described in terms of knowledge-as-elements perspectives.

Summary and Synthesis of Knowledge-as-Elements Perspectives

In summary, knowledge-as-elements perspectives hypothesize that naïve knowledge structures consist of multiple conceptual elements including, but not limited to, phenomenological primitives, facts, facets, narratives, concepts, and mental models at various stages of development and sophistication. Novices spontaneously connect and activate these knowledge pieces according to the relevance of the situation. During the conceptual change process, the elements and interactions between the elements are revised and refined through addition, elimination, and reorganization to strengthen the network. From this perspective, conceptual change involves a piecemeal evolutionary process rather than a broad theory-replacement process.

COMPARISON OF THE TWO VIEWS

There are significant similarities and differences between knowledge-as-theory and knowledge-as-elements perspectives. Table 1 provides a summary of

Table 1. Summary Comparison of Knowledge-as-Elements and Knowledge-as-Theory Perspectives.

Agreements	
Learners acquire knowledge from their daily experiences.	
Learners' naïve knowledge influences their formal learning.	
Much naïve knowledge is highly resistant to change. Thus, conceptual change is a time consuming process.	
Disagreements	
Knowledge-as-Theory Perspectives	**Knowledge-as-Elements Perspectives**
Naïve knowledge is highly organized in theory, schema, or frame forms.	Naïve knowledge is a collection of quasi-independent knowledge elements.
Naïve knowledge in a coherent form has explanatory power to consistently interpret the situations across broad domains.	Consistent application over time for individual contexts, and systematicities will be present, but high contextual sensitivity.
More focus on revolutionary replacement of naïve knowledge in a manner similar to Kuhn's perspectives on paradigms in science. Significant coherence between ideas at any given point in time.	More focus on conceptual change involving evolutionary revision, refinement, and reorganization. Multiple conflicting ideas may coexist simultaneously at any given point in time.
Explanations involve the creation of mental models constrained through the overarching framework theories or ontological categories.	Explanations involve the p-prims and other elements within the learner's conceptual ecology that are most strongly cued by the context.

some of these key similarities and differences. The subsequent sections provide further discussion and clarifications of these agreements and disagreements.

Agreements

Obviously, there are significant areas of agreement and overlap between the two perspectives. We first outline and discuss some of these areas of similarity and later discuss some of the core differences.

Learners acquire knowledge from their daily experiences. Both perspectives agree that novices' conceptual knowledge is heavily influenced by everyday experiences with natural phenomena and events. Therefore, novices' explanations often include scientifically non-normative explanations based on their daily experiences. In order to teach normative scientific theories and concepts, we have to know what students think and then adjust instruction accordingly.

Learners' naïve knowledge influences their formal learning. In addition to influencing their causal explanations, students' prior knowledge influences their formal learning. Students come to formal science instruction with a diverse set of alternative conceptions or misconceptions concerning natural phenomena and events. These alternative conceptions of phenomena and events are often incompatible with scientifically normative ones. Knowledge-as-theory perspectives suggest that if core framework theories can be influenced through instruction, misconceptions will be replaced as changes to the framework theory revision ripple outward through the rest of the connected framework. Knowledge-as-elements perspectives view misconceptions as individual components that require revision and refinement to connect more productively with a more normative conceptual framework. Hence elemental perspectives tend to suggest a bottom-up approach rather than a top-down approach.

Much naïve knowledge is resistant to change. Much naïve knowledge is highly resistant to change by conventional teaching strategies because of its entrenchment in everyday experiences. A number of studies report that students still maintain certain alternative conceptions in spite of substantial instruction.

Disagreements

While there are important similarities in the predictions and expectations of the two perspectives, there are, however, also significant differences between the perspectives. We now outline and discuss some of the most critical differences.

Differences in structural properties of naïve knowledge. The first difference between the two perspectives is about the structure of naïve knowledge. From knowledge-as-theory perspectives, naïve knowledge is highly organized into theory, schema, or frame forms. The root of this theory comes from Piaget's early work and has been strengthened by the similarities between early scientists' knowledge structure and naïve knowledge structure. In other words, knowledge-as-theory perspectives analogize naïve conceptions to naïve theories. On the other hand, knowledge-as-elements perspectives propose that naive knowledge is a collection of quasi-independent simple elements within a larger conceptual ecology that are loosely connected into larger conceptual networks without an overarching structure. Knowledge-as-elements perspectives therefore predict (1) consistent application of ideas over time for individual contexts along with definite systematicities but (2) high contextual sensitivity. Knowledge-as-elements perspectives also predict that individuals may simultaneously maintain multiple conflicting ideas on a regular basis.

Dispute about consistency vs. inconsistency. Another difference between the two perspectives focuses on the domain size across which a novice's predictions and explanations should be consistent. According to knowledge-as-theory perspectives, fundamental presuppositions, ontological and epistemological commitments, (e.g., heavy objects fall faster) are embedded in naïve theories and students explanations are constrained by them. Therefore, a naïve theory guides a novice to make consistent predictions and causal explanations across multiple contexts spanning broad domains (that may or may not parallel the domains of related normative concepts). Furthermore, there should be much coherence between ideas. On the other hand, from knowledge-as-elements perspectives, novices' knowledge structures are much more contextually sensitive. A novice's predictions or explanations will be consistent for specific related contexts over time, but this consistency doesn't extend across broad domains because of the contextual sensitivity of the constituent elements and cuing relationships. Therefore, while there will be local systematicities in novices' predictions and explanations, knowledge-as-elements perspectives suggest that novices' will not demonstrate consistency across broad domains.

Revolutionary vs. Evolutionary change. A third important difference between the perspectives focuses on the nature of change processes. Knowledge-as-theory perspectives often suggest revolutionary change where current concepts are abandoned and replaced with normative concepts. According to knowledge-as-theory perspectives, novices already have extensive well-defined theoretical structure from the beginning. Novices need to add new knowledge elements into the existing conceptual structure and/or modify the existing knowledge elements of their conceptual structure in order to replace their initial theory with the scientific one. The change is basically defined as holistic and dramatic, although many theorists acknowledge that the process is often time consuming and lengthy. The important idea is that revolutionary change occurs between distinct understandings or models that are theory-like in character. Thus, there should be significant coherence between ideas at any point along the change process.

Knowledge-as-elements perspectives propose a more evolutionary trajectory without such distinct phases or stages. Learning involves the gradual accretion and piecemeal eliminations, additions, and organization of elemental knowledge pieces where multiple contradictory ideas can coexist within a student's conceptual ecology. Knowledge-as-elements perspectives suggest that the knowledge-forming process begins with quasi-independent small knowledge elements that get connected to create more complex (hopefully more normative) conceptual structures by adding new knowledge elements, reorganizing connections, and/or modifying existing simple knowledge elements through an evolutionary process. This contrasts with knowledge-as-theory perspectives that suggest revolutionary processes of conceptual change where one theory-like understanding is replaced by another theory-like understanding.

Empirical Evidence for Conceptual Change Theories

Historically, the research literature has predominantly leaned toward knowledge-as-theory perspectives (diSessa, 2006; Driver, 1989). We now discuss arguments and educational implications that potentially support the adoption of knowledge-as-elements perspectives. In particular, we now present some recent research findings on knowledge structure coherence that lead us to lean toward the knowledge-as-elements perspective. First we discuss a series of studies and replication studies by Ioannides and Vosniadou (2002), diSessa, Gillespie, and Esterly (2004), and Özdemir and Clark (in preparation). We then present data from several other related studies.

Ioannides and Vosniadou (2002) investigated the meaning of force and its development among 105 children across four age levels. What they found was that 88.6% of the subjects' responses fell into seven categories of internally consistent interpretations of force. The seven categories include: (a) internal force, (b) internal force affected by movement, (c) internal and acquired force, (d) acquired force, (e) acquired force and force of push/pull, (f) force of push/pull, and (g) gravitational and other forces. For example, a student with internal force meanings always explained that force is related to an objects' size or weight. The students in this study thus made consistent predictions and gave consistent explanations regardless of context. Therefore, the Ioannides and Vosniadou concluded the students' interpretations of force were uniform and internally consistent.

diSessa et al. (2004) conducted a quasi-replication and extension of the Ioannides and Vosniadou study. diSessa et al. found that students' meaning of force could not be explained by the coherence claim. Students' responses were inconsistent across contexts, even in the replication part of the study. The results of the study also support several alternative explanations in which the learner's understanding of force is context-dependent. The findings supported earlier work suggesting that naïve knowledge consists of unstructured small pieces that are unconsciously activated in certain circumstances (diSessa, 1993). Indeed, even the color of an object could affect the explanations of kindergarten students in responding the questions of force.

The conflicting findings between the Ioannides and Vosniadou (2002) study and diSessa et al.'s quasi-replication (2004) suggested the need for further clarification. Recently, Özdemir and Clark (in preparation) conducted a replication study with four age groups of Turkish students to resolve the coherence vs. fragmentation dispute about students' understanding of force. The study applied the coding schemes based on both Ioannides and Vosniadou (2002) and diSessa et al. (2004). The results of the study suggest that students' interpretation of force supports knowledge-as-elements perspectives overall. The results of this study also indicate that methodological flaws such as employing soft coding schemes and assessing students' understanding of force in limited number of contexts can overestimate students' knowledge coherence. Even small contextual variations may affect students' interpretations of force and, thus, this causes fragmentation in their causal responses.

In addition to this series of replications and quasi-replications, several other recent studies investigating the debate have provided further support for knowledge-as-elements perspectives. First among these, Southerland, Abrams, Cummins, and Anzelmod (2001) explored the nature of students' biological knowledge structure. They concluded that p-prims have more explanatory power than conceptual frameworks theory regarding the shifting nature of students' conceptions of biological phenomena. Second, diSessa, Elby, and Hammer (2002) documented contradictory claims and explanations for the same situation in different occasions in the domain of force and motion. Third, Thaden-Koach, Dufresne, and Mestre (2006) investigated fifty college students' understanding about moving objects by using coordination class theory (diSessa & Sherin, 1998). The result of the study highlights the contextual sensitivity. Thus, they concluded that " …learning in a domain like physics is a complex endeavor requiring considerable time, instructional resources, and appreciation of the complexity of applying ideas across diverse contexts (p. 10)." Fourth, Wagner's (2006) case study analysis suggests that students' conceptual understanding is often highly context sensitive and that transfer therefore requires the acquisition of abstract representations by means of "the incremental refinement of knowledge resources that account for-rather than overlook-contextual variation (p.1)." Finally, Clark's (2006) longitudinal study in thermodynamics showed that students' explanations evidenced multiple contradictory ideas, disruptive experientially supported ideas, difficulties productively connecting normative ideas, and the active pursuit of idiosyncratic explanations. That study demonstrates that "students' understanding of thermal equilibrium evolve from disjointed sets of context-dependent ideas toward, if not achieving, integration, normatively, and cohesiveness (p. 467)."

Therefore, although researchers are still debating this issue and there is not yet consensus on knowledge structure coherence and the mechanisms of conceptual change, our view aligns more closely with the knowledge-as-elements perspective because of the results of these recent studies.

IMPLICATIONS FOR INSTRUCTION

The implications of these disputes for instruction are profound. Determining whether students' intuitive knowledge consists of many quasi-independent elements, as suggested by knowledge-as-elements perspectives, or of a network of theories, as suggested by knowledge-as-theory perspectives, is critical; it affects our understanding of the conceptual change process, curriculum design, and instructional strategies. If a learner's understanding is theory-like, and if certain specific conditions are met, the learner will become dissatisfied with existing conceptions when conflicting examples are introduced to the learner (Strike & Posner, 1982). It is believed that such conceptual conflict could make the learner abandon existing misconceptions and accept scientifically appropriate alternatives if the learner could not otherwise dismiss, ignore, or reinterpret them within the existing framework (Chinn & Brewer, 1993). On the other hand, if a learner's intuitive knowledge is elemental in nature, instruction should focus on how those elements are activated in appropriate contexts. Teachers may first make students aware of their central pieces of knowledge and then allow students to use them in appropriate contexts. From this perspective, productive curriculum design might confront students with the same phenomena in different contexts. The curriculum would therefore focus more on a refinement processes including addition, modification, elimination, and organization of the knowledge elements in learner's knowledge structure over time.

From a constructivist view, all of the various elements in a student's conceptual network are subject to progressive knowledge construction. School science often conflicts with students' intuitive knowledge. If we merely target students' misconceptions with replacement procedure as suggested by radical revolutionary models, we might only achieve these replacements in a limited number of contexts which might remain independent of students' interpretations of experiences outside of the classroom. Therefore we should attempt to help students reorganize and reprioritize the elements and connections of their conceptual network if we want to allow students to construct a scientific theory that is applicable to a number of situations. This cognitive process cannot be achieved by interpreting students' knowledge structures with small number of mental representations or conceptual schemes.

Because constructivism sees students' existing ideas as a primary source for learning, erasing misconceptions with a replacement model is at odds with this paradigm. In their paper, Smith, diSessa, and Roschelle (1993) extensively discuss how traditional view on misconceptions and the process of conceptual change are at odds with constructivism:

> Our central claim is that many of the assertions of misconceptions research are inconsistent with constructivism. Misconceptions research has emphasized the flawed results of student learning. Constructivism, in contrast, characterizes the process of learning as the gradual recrafting of existing knowledge that, despite many intermediate difficulties, is eventually successful. It is difficult to see how misconceptions that (a) interfere with learning (b) must be replaced, and (c) resist instruction can also play role of useful prior knowledge that supports students' learning. If we take constructivism seriously, we must either reconsider the solely mistaken character of misconceptions or look for other ideas to serve as productive resources for student learning (p.123-124).

When we look at conceptual change from diSessa's epistemological stance, we should attempt to help students reorganize and reprioritize the elements and connections of their conceptual network. P-prims such as force as mover, dying away and spontaneous resistance describe the events in the physical world in terms of intuitive conceptualization (diSessa, 1993). The idea is that these p-prims should be cued in several appropriate contexts to build more complex and stable formal knowledge. In this case, p-prims within the students' alternative conceptions take a function to serve as productive tools for expertise. For example, the function of the dying away conception can be invoked as part of formal concepts and learning (diSessa, 2006). In a simple event, tossing a ball into the air, students naturally recognize that the motion of the ball eventually dies away. This knowledge element is often self explanatory in the sense that there is no need to explain the cause of the event. However, if the causality behind a novice's explanation is investigated, the novice most probably raises the concept of gravity. Novices might say that the upward force on the ball is decreased by gravity until a balance occurs between the upward force and gravity at the peak in the air. Although this causality is non-normative, it provides extremely useful building blocks for the process of refining a student's understanding of the concept of conservation of energy and the concept of momentum in science.

In terms of specific instructional strategies, knowledge-as-elements perspectives suggest that conceptual change requires restructuring, editing, and organizing rather than discrete changes from one conception to another especially for complex and rich domains such as mechanics and thermodynamics. Toward this goal, engaging students with multiple computational representations suggests great promise for instruction. More specifically, instruction engaging multiple representations can re-represent concepts in multiple ways to highlight specific variables within each context separately while ignoring the others (Ainsworth, 1999). The complexity of a phenomenon can be simplified to help a learner focus on the specific aspects of the phenomenon across multiple contexts. Parnafes (submitted) investigated students' learning processes about physical phenomena through computational representation. Her research was grounded upon a knowledge-as-elements perspective. Her analyses suggested that (1) instruction engaging multiple representations can highlight the important aspects of phenomena so that a learner can easily see and differentiate between them, (2) instruction engaging multiple representations can help students identify fragmentation in their causal responses and encourage students to engage in conflict resolution and coherence-building between ideas, and (3) instruction engaging multiple computational representations can provide interactive visual aids for the investigation of phenomena. Therefore, while multiple instructional strategies can offer synergistic benefits, instruction engaging multiple computational representations seems particularly powerful from knowledge-as-elements perspectives.

FINAL THOUGHTS

In our review, we have outlined key features of knowledge-as-elements and knowledge-as-theory perspectives. There is likely no single truth to explain the complex processes of conceptual change and naïve knowledge structure. One possibility is that the degree of the richness of a scientific domain might be an indicator to decide which theory is more useful for describing and analyzing conceptual change. For example, diSessa developed his knowledge-as-elements perspectives for the rich domain of mechanics while Vosniadou's knowledge-as-theory perspectives were developed in domains with which students have less first-hand interaction (e.g., astronomy).

A key issue to consider is that students' learning processes and trajectories may involve periods and aspects of both coherence and transition. Fewer and fewer researchers currently espouse radical knowledge-as-theory perspectives. Wiser and Amin (2001) for example suggest that conceptual change involves both revolutionary as well as evolutionary components. Similarly, Susan Carey suggests that both strong and weak restructuring occurs and that the process takes time. Stella Vosniadou also agrees that the process takes time and that students may temporarily embrace multiple "synthetic models" between stages. At the same time, diSessa and others are currently working on research about coordination classes to explain systematicities and connections between ideas rather than focusing predominantly on the quasi-independence of the various elements. There is therefore a convergence toward the center of these perspectives in order to account for coherence, systematicity, and transition.

Ultimately, knowledge-as-elements perspectives may prove most useful because they provide more tools with which to interpret times of transition in students' understanding even if students' initial understandings (and even intermediate stages) are indeed theory-like in nature. The knowledge-as-theory perspectives discussed above acknowledge that conceptual change may take extended periods of time, but they generally provide less detail about the mechanisms for these transitions. Tools for explaining and modeling transitional times are critical, because these transitional times may extend across many school grades and on into adulthood. Therefore, although there are strong arguments from knowledge-as-theory perspectives regarding the theory-like understandings of young children, for example in terms of a naïve biology (e.g., Inagaki & Hatano, 2002; Carey, 1999) or even astronomy (e.g., Vosniadou & Brewer, 1994), the arguments are much less strong for older students. Ioannides and Vosniadou (2002) for example, present data that is compelling regarding the coherence of younger students' understanding about the concept of force, but that study presents less compelling data regarding the coherence of older students' understandings, which can only be grouped into a catch-all category of "gravity and other." Older students' understandings therefore seem much more transitional and fragmented. This transition has been shown to extend well into adulthood, if not permanently. Clarks' (2006) longitudinal study of students understanding of thermodynamics tracked students from eighth grade through twelfth grade and showed ongoing transition across these years. Therefore, even if for the sake of argument we accept that young students' exhibit naïve knowledge with theory-like attributes, the strongest argument for knowledge-as-elements perspectives may be that it can account both for coherent phases as well as transitional phases while knowledge-as theory-perspectives focus primarily on phases of the process that appear much more ephemeral after the early years.

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REFERENCES

Ainsworth, S. (1999). The functions of multiple representations. *Computers and Education*, *33*, 131-152.

Anderson, J. R. (1993). *Rules of the mind*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Brown, D. (1995, April). *Theories in pieces? The nature of students' conceptions and current issues in science education*. Paper presented at the 1995 Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Carey, S. (1991). Knowledge acquisition: Enrichment or conceptual change? In S. Carey & R. Gelman (Eds.), *The epigenesis of mind* (pp. 257-291). Hillsdale, NJ: Lawrence Erlbaum Associates.

Carey, S. (1999). Sources of conceptual change. In E. K. Scholnick, K. Nelson, & P. Miller (Eds.), *Conceptual development: Piaget's legacy* (pp. 293-326). Mahwah, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H. (1992). Conceptual change in and across ontological categories: Examples from learning and discovery in science. In R. Giere (Ed.), *Cognitive models of science* (pp. 129-160). Minneapolis. MN: University of Minnesota Press.

Chi, M. T. H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *The Journal of the Learning Sciences, 14*(2), 161-199.

Chinn, C. A., & Brewer, W. F. (1993). The role of Anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research, 63*, 1-49.

Clark, D. B. (2006). Longitudinal conceptual change in students' understanding of thermal equilibrium: An examination of the process of conceptual restructuring. *Cognition and Instruction, 24*(4), 467-563.

Driver, R. (1989). Students' conceptions and the learning of science. *International Journal of Science Education, 11*, 481-489.

diSessa, A. A. (1988). Knowledge in pieces. In G. Forman & P. B. Pufall (Eds.), *Constructivism in the computer age* (pp. 49–70). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and Instruction 10*(2 & 3): 105-225.

diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

diSessa, A.A., Elby, A., & Hammer, D. (2002). J's epistemological stance and strategies. In G. Sinatra and *Pintrich* (Eds.), *Intentional conceptual change* (238-290). Mahwah, NJ: Lawrence Erlbaum Associates.

diSessa, A.A., Gillespie, N., & Esterly, J. (2004). Coherence versus fragmentation in the development of the concept of force. *Cognitive Science, 28*, 843-900.

diSessa, A.A., & Sherin, B.L. (1998). What changes in conceptual change, *International Journal of Science Education*, 20, 1155-1191.

Hatano, G., & Inagaki (1996). Cognitive & cultural factors in acquisition of intuitive biology. *The Handbook of Education & Human Development*. Olson and Torrance.

Harrison, A., G., Grayson, D., J., & Treagust, D., F. (1999). Investigating a grade 11 student's evolving conceptions of heat and temperature. *Journal of Research in Science Teaching, 36*(1), 55-87.

Hewson, P.W. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*, 383-396.

Hewson, M. G., & Hamlyn, J. (1984). The influence of intellectual environment on conceptions of heat. *European Journal of Science Education, 6*, 245-262.

Hunt, E., & Minstrell, J. (1994). A cognitive approach to the teaching of physics. In K. McGilly (Ed.),*Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 51–74). Cambridge,MA: MIT Press.

Inagaki, K., & Hatano, G. (2002). *Young Children's Thinking about Biological World*. Philadelphia, PA: Psychology Press.

Ioannides, C., & Vosniadou, S. (2002). The changing meaning of force. *Cognitive Science Quarterly, 2*, 5-61.

Linder, C.J. (1993). A challenge to conceptual change. *Science Education, 77*, 293-300.

Linn, M. C., Eylon, B., & Davis, E. A. (2004). The Knowledge Integration Perspective on Learning. . In M. C. Linn, E. A. Davis & P. Bell (Eds.), *Internet environments for science education*. Mahwah, NJ Lawrence Erlbaum Associates.

Kuhn, T. (1962). *The structure of scientific revolution*. Chicago, the University of Chicago Press.

McCloskey, M. (1983). Naïve theories of motion. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 299-324). Mahwah, N.J.: Lawrence Erlbaum Associates.

Özdemir, G., & Clark, D.B. (in preparation). Coherence versus fragmentation: A study of Turkish students' understanding of force.

Parnafes, O. (submitted). What does "fast" mean? Understanding the physical world through computational representations. *The Journal of Learning Science*.

Pfundt, H., & Duit, R. (1994). Bibliography: Students' alternative frameworks and science education (4th ed). Kiel: IPN.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Smith, E. L., Blakeslee, T. D., & Anderson, C. W. (1993). Teaching strategies associated with conceptual change learning in science. *Journal of Research in Science Teaching, 30*, 111-126.

Smith, J.P., diSessa, A. A., & Roschelle, J. (1993). Misconception reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Science, 3*, 115-163.

Southerland, S.A., Abrams, E., Cummins, C.L. & *Anzelmo*, J. (2001). Understanding students' explanations of biological phenomena: Conceptual frameworks or p-prims. *Science Education, 85*, 311-327.

Strike, K.A., & Posner, G.J. (1982). Conceptual change and science teaching. *European Journal of Science Education, 4*, 231-240.

Strike, K.A., & Posner, G.J. (1992). A revisionist theory of conceptual change. In R.Duschl & R. Hamilton (eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 147-176). Albany, NY: SUNY Press.

Tao, P-K. & Gunstone, R.F. (1999). The process of conceptual change in force and motion during computer-supported physics instruction. *Journal of Research in Science Teaching, 36*, 859-882.

Thaden-Koach, T.C., Dufresne, R.J., & Mestre, J.P. (2006). Coordination of knowledge in judging animated motion, *Physics Education Research, 2*, 020107.

Thagard, P. (1992). *Conceptual revolutions*. Princeton, NJ: Princeton University Press.

Ueno, N. (1993). Reconsidering p-prims theory from the viewpoint of situated cognition. *Cognition and Instruction*, *10*(2&3), 239-248.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4*, 45-69.

Vosniadou, S., & Brewer, W.F. (1992). Mental models of the earth. A study of conceptual change in childhood. *Cognitive Psychology, 24*, 535-585.

Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science, 18*, 123-183.

Vosniadou, S., & Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. *International Journal of Science Education, 20*, 1213-1230.

Wagner, J.F. (2006). Transfer in pieces, *Cognition and Instruction*, *21*, 1-71.

Wellman, H. M.,&Gelman, S. (1992). Cognitive development: Foundational theories of core domains. *Annual Review of Psychology, 43*, 337–375.

Wiser, M., & Amin, T. (2001). "Is heat hot?" Inducing conceptual change by integrating everyday andscientific perspectives on thermal phenomena. *Learning and Instruction, 11*, 331–353.

Wiser, M., & Carey, S. (1983). When heat and temperature were one. In D. Gentner & A. Stevens (Eds.), *Mental models* (pp. 267-298), Hillsdale, NJ: Lawrence Erlbaum Accociates, Inc.

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Correlates of Academic Procrastination and Mathematics Achievement of University Undergraduate Students

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Procrastination is now a common phenomenon among students particularly those at the higher level. And this is doing more harm to their academic achievement than good. Therefore, this study examined the correlates between academic procrastination and mathematics achievement among the university mathematics undergraduate students. The study used a total sample of 150 part 3 and 4 students in the department of mathematics and mathematics education students in the university of Ibadan and university of Lagos, Nigeria. The 35 items academic procrastination scale developed and validated by Tuckman (1991) was used for the collection of data, in conjunction with the subjects GPA scores till date in mathematics. Findings indicates that: a significant correlation was found in the academic procrastination and academic achievement of the subjects in mathematics, significant difference also exists in the levels of procrastination and mathematics achievement of the subjects, with low procrastinators performing better than the moderate and the high procrastinators. Results further reveals the subjects procrastinate the same way irrespective of their gender. Implications of procrastination on academic achievement of students at all levels generally and some effective ways of remediation of procrastination were suggested.

Keywords: Academic Procrastination, Mathematics Achievement, Academic Achievement, Gender, Undergraduates.

INTRODUCTION

The issue of procrastination is no more something to toy with in academics but something to deal with. This is because procrastinatory behaviour is now a common phenomenon among students particularly at the college and university levels. This is recognised to be doing more harms than good to the academic achievement of the Undergraduate Students most especially the mathematics major.

It is worthy to note that the lives of university students are characterized by frequent deadlines given by university teachers and administrators to carry out various responsibilities such as registration for courses, completion of course forms and submission of class assignments or term papers (Popoola, 2005). A

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common form of academic procrastination among students is waiting until the last minute to turn in papers or to study for an examination (Migram, Batin & Mower, 1993). According to (Oweini and Haraty, 1993) college students are notorious for procrastination. They refer to procrastination as the acts of needlessly delaying a task until the point of some discomfort. Procrastination is a behavioural problem that many adults experience on a daily regular basis (Jansen and Carton, 1999) particularly on task which should be completed by a specific deadline (Oweini and Haraty, 2001).

Mathematics is an important school subject because it is associated with more academic and or career opportunities (Akinsola and Tella, 2003). Burton cited in Agwagah and Usman (2003) relates the importance of mathematics to the scientific, industrial, technology and social progress of a society. It is a science that studies numbers, shapes, objects and their properties which are needed as basic requirement for all sciences. That mathematics is an important subject is undebatable. But it is very sad to note that the performance by undergraduate students particularly the majors in the subject in recent time are not encouraging. This can be attributed to the fact that majority of mathematics undergraduate students has been observed to be procrastinators. This is confirmed by the observation by (Ferrari and Beck, 1998) that over 70% of college students engaged in frequent academic procrastination, most commonly with writing term papers.

Procrastination is probably the single most common time management problem (Learning Common Fastfacts Series, 2004). One basic thing about procrastination is that everyone procrastinates to some extent. However, some reasons can be put forward why university students rank highly among those mostly vulnerable to procrastination (Learning Commons Fastfacts Series, 2004). The reasons according to this group are: (i) there is always a tremendous amount of work to do. Regardless of how much time the students spend studying, it can seem impossible to get finished; (ii) for most students, only a few hours each day are spent in class and labs. The majority of time is unstructured, and students are responsible for deciding what to do and when to do it; and (iii) in the university environment, particularly in residence, there is usually something more enjoyable to do than studying. Many activities compete for a limited number of hours in a week, and studying is often pushed to the bottom of the list.

It also recognized that many mathematics students refer to the subjects as being difficult. And the (Learning Commons Fastfacts Series, 2004) have already asserts that procrastination often results when a task seems difficult, unpleasant, or overpowering. It seem reasonable to realise at this point that if the college or university mathematics students continue to procrastinate, definitely the weak manifestation of academic achievement in the subject will as a matter of fact continue. In the light of this, the present study is design to examine the correlates of academic procrastination and mathematics academic achievement of undergraduate students. It will also find out whether there is gender difference in academic procrastination of the students before finally come out with possible ways of remediating the behaviour for effective academic achievement in mathematics courses.

Literature Review

Lay (1986) conceived procrastination as a frequent failure at doing what ought to be done to reach goals. Ellis and Knaus (2002) perceive procrastination as the desire to avoid an activity, the promise to get it late, and the use of excuse making to justify the delay and avoid blame. Popoola (2005) considered procrastination as a dispositional trait which has cognitive, behavioural and emotional components. Noran (2000) defines the term as avoiding doing a task which needs to be accomplished. He explains that one would rather be spending time socializing with friends or relatives rather than working on an important work project that is due soon; or one would rather be watching an exciting movie at the cinema or television rather than study for upcoming quiz or test. Popoola (2005) describes the procrastinator as someone who knows what he wants to do in some sense, can do it, is trying to do it, yet doesn't do it. Solomon and Rothblum (1984) posited that people tend to avoid tasks which they find unpleasant and engaged in activities which are more rewarding, especially with short term over long term gain. Ferrari and Emmons (1995) found that procrastinator have low self esteem and delay task completion because they believe they lack the ability to achieve a task successively. While Popoola (2005) further asserts that an individual postpones doing things that make him or her anxious, apprehensive, or likely to lose face in the presence of peers (Milgram, Dangour and Raviv, 1992). Effert and Ferrari (1989) demonstrate that procrastinators lack self-efficacy, self-esteem and are publicly self-conscious and highly self-critical. The researcher added that procrastinator often have perfectionism expectations, and are over-conscious. They display irrational fear of success or failure which may lead to neurotic avoidance. They may also be emotional, overwhelmed and anxious, having less need for cognitive complexity and are more likely to attribute success to external and unstable factors (Solomon and Rothblum, 1984).

Furthermore, Noran (2000) considers a procrastinator as someone who knows what he/she want to do, is equipped to perform the task, is trying and planning to perform the task, but does not complete the task, or excessively delays performing the task. To him, the procrastinator will work on less important obligation, rather than fulfilling the more important obligation, or (s) he may use his or her time wastefully in some minor activities or pleasure. In most cases, procrastinators' keep themselves ready to work but avoiding the activity. Procrastination has been found to result from cognitive distortions of faulty thinking (Ellis and Knaus, 1977) and also related to problems of perceiving and estimating time (Aitken, 1982). Noran (2000) explains that procrastinator in the first category often has perfectionist expectations and is over-conscious. They believed to fear success or failure which eventually leads to neurotic avoidance. They lack self-efficacy and self-esteem, and are self-conscious and self-critical. While however, impulsive procrastinators' may fail to pick up cues from the environment (Ferrari and Emmons, 1994). Reasons put forward as relate to this category of procrastination include the inability to delay gratification of pleasure lacking self-control, lacking motivation for achieving targeted goals, and lacking energy or organizational abilities. Ferrari and Emmons (1995) emphasized that researchers have identifies different types of academic procrastination, such as low conscientiousness and anxiety-related procrastination. Academic procrastinators typically make four cognitive distortions which promote and maintain their task avoidance. These are: overestimation of time left to perform task, underestimation of time require completing tasks; overestimation of future motivational states; misreliance on the necessity of emotional congruence to succeed at task, and belief that working when not in mood to work is sub-optional (Noran, 2000).

This review will not be completed without stating the causes of procrastination. According to Noran (2000) the literature has reveals several causes for procrastination. He identifies the following as the possible causes.

Time Management-To him, someone who procrastinates suggests he/she is unable to manage time wisely. It implies uncertainty of priorities, goals and objectives. There is also a feeling of overwhelms doing a certain task. Subsequently, one postpones doing academic assignment for a certain data, while focusing on unproductive activities.

Inability to concentrate or having low levels of conscientiousness or ones work is a second reason for procrastination- This difference may be due to distortions in the environment, such as noise, cluttered study desk or trying to do an assignment on a bed. A third factor for procrastinating is the fear and anxiety related to failure. A person in this category would spend more time worrying about forthcoming tests and projects rather than plan for it and completing them. Negative belief about ones capability is another reason to procrastinate. - Unrealistic expectation and perfectionism may also be another blocking hurdle for procrastination.

Tucuman's (1990) review summarized research findings on causes of procrastination as follows: "disbelieving in ones own capability to perform a task; being unable to postpone gratification, and assigning blame to external sources" p4). Procrastination is also associated with high levels of stress, low self-esteem, low self-efficacy, self-denigration, lower level of resourcefulness', higher levels of self-conscouiousness, self-handicapping and depression (Flet, Blankestein, & Martin 1995).

Research findings on the proportion of students who procrastinate have not been consistent (Popoola, 2005). For instance, while Solomon and Rothblum (1984) estimated that at least half of all students consistently and problematically procrastinate, Ellis and Knaus, (1977) found that the number of students who procrastinate at some point approaches 95%. Similarly a review by Ferrari and Beck (1998) reveals that students engage in frequent procrastination and this occurs regardless of race or gender. In a study of 374 undergraduate students by the procrastination research group at Carleton University in Ottawa, it was found that procrastination is related to not only higher stress and poor coping strategies, but also avoidance behaviours (Sirois and Pychyl, 2002). It was reveals from the study that students who suffer from these avoidance coping styles resist completing assignments and addressing other deadlines that evoke tension and anxiety. Tuckman (2003) research on study skills demonstrates that by teaching students' specific learning and motivational strategies it is possible to modify avoidance behaviour. The study compared a group of 397 students who completed Tucumán's semester long course, Individual Learning and Motivation (ILM) to a group of 397 students who did not enrol in the course. Those students who received the strategy training earned significantly higher GPAs .48 point higher than those who did not complete the training.

In conclusion therefore, it is not an overstatement to state that procrastination may have debilitating effects on university students' performance particularly the mathematics majors. The finding by (Tice and Baumeister, 1997) that procrastinators received significantly lower paper and examination grades than non-procrastinators is very relevant here. Perhaps evidence abounds in research studies that procrastination is usually result to poor academic performance (Tuckman, Abry, and Smith, 2002; Beck, Koons and Morgan, 2000 and Wesley, 1994). It is on this note that the present study is design to find out the correlation between academic procrastination and mathematics academic achievement; and in addition examine whether gender difference exist in academic procrastination among the mathematics students in a population of Nigerian undergraduate students where study of this kind is not common. To achieve the objectives of this study, the following hypotheses were generated:

1. There will be no significant correlation between procrastination and mathematics academic achievement.
2. There will be no significant difference in the academic achievement of the Participants based on their level of procrastination(Low, Moderate and High)
3. There will be no gender difference in the academic procrastination of the participants.

METHOD

The study adopted a causal descriptive research design approach. This does not involve the manipulation of any variables. It only carefully observes and records information about the population as it naturally occurred during the time the study was conducted.

The population of the study comprises150 part 3 and 4 students who were selected through a total enumeration sampling method from the department of mathematics and mathematics education of the University of Ibadan and University of Lagos, Nigeria. Despite the use of total enumeration in the sample selection, the sample was still small. This is based on the consideration by many students that Mathematics is difficult which make many of them to be running away from the course. The two cities are the most populous town in Nigeria where stress factors could be a major hindrances to academic achievement .The age of these participants ranged from 20-36 years with a mean age of 24.6years.

A validated academic procrastination scale comprises of 35 likert type items developed by Tuckman (1991) with the original reliability coefficient of r =. 90 Cronbach alpha was used for the collection of data on academic procrastination. This instrument was revalidated before use and the Mathematics students of Obafemi Awolowo University, Ile Ife, Nigeria were used to determine the reliability of the questionnaire which gave an r = .88 through the same cronbach alpha.

The participant grade performance average GPA in mathematics till date was taken from their academic record. This represents the participants' academic achievement scores.

All the participants were administered the Tuckman Academic Procrastination Scale in a classroom under normal examination situation. This was to reduce the mortality rates of the instrument and interaction of the participants which may distort the results of the study. Data collected on the study were analyzed using Pearson product moment correlation, analysis of variance, and multiple comparison and t-test statistical tools.

RESULTS

The results of the analysis are presented as follows: Hypothesis 1: There will be no significant correlation between academic procrastination and Mathematics academic achievement.

Table 1 above shows that there is significant correlation between academic procrastination and Mathematics academic achievement with r= 0.82. This implies that the more the subjects procrastinate the more their achievement in mathematics diminished or decreased.

Hypothesis 2: There will be no significant difference in the academic achievement of the subjects based on their level of procrastination (Low, Moderate and High).

Table 1. Correlation between Procrastination and Mathematics Achievement

Variables	N_o	X	SD	r	P
Aca.Procastination	150	49.5	14.8		
Maths Achievement	150	47.6	13.6	0.82	<0.05

Table 2. Level of Procrastination and Mathematics Achievement

Source of variance	Sum of squares	df	Mean squares	F	P
Between Groups	82.66	2	41.33		
Within Group	280.28	147	1.58	26.2	<0.05
Total	362.94	149			

Table 3. Multiple comparison of Mathematics Achievement of the Subjects and Their Level of Procrastination.

Level of procrastination	No	X	SD	Mean Difference	Std.Error	P
Low procrastinator	42	3.44	0.53			
Moderate Procrastinator	58	2.65	0.78	0.79*	0.131	<.05
Low procrastinator	42	3.44	0.53			
High Procrastinator	50	2.53	0.33	0.94*	0.86	<.05
Moderate Procrastinator	58	2.65	0.78		0.111	>.05
High Procrastinator	50	2.53	0.33	0.12		

Table 4. Gender Difference and Academic Procrastination.

Variables	No	X	SD	df	t.obs	t.crit.	P
Male	85	56.2	10.2	148	0.19	1.96	0.05
Female	65	55.9	9.8				

Table 2 above shows that there is a significant difference in the level of procrastination and Mathematics academic achievement of the subjects with F.obs= 26.2*at P< 0.05 with 2 degree of freedom.

To identify the procrastinating group that has a better achievement over the other, t-test analysis was carried out in pairs. The result is shown in table 3.

From the table 3 above low procrastinators had a mean CGPA of 3.44and a standard deviation of 0.53 while moderate procrastinators had a mean of CGPA of 2.65 and a standard deviation of 0.78. The difference between the mean values of the two groups (0.79) is statistically significant at 0.05 levels. This indicates that a significant difference exists between the academic achievement of low and moderate procrastinators with low procrastinators performing better than the moderate procrastinators. Furthermore, data on the CGPA of low procrastinators (x =3.44, SD.0.53) were compared with those of high procrastinators(x= 2.53, SD = 0.33). This analysis showed a mean difference of 0.94, which is significant at 0.05 levels. This indicates that the academic achievement of low procrastinators as measured by their GPA were better than those of high procrastinators (P<.05). On the other hand, another comparison of the mean GPA of moderate (X=2.65, SD= 0.78) and high procrastinator (X=2.53, SD =0.33) showed a mean difference of 0.12 which is not significant at 0.05 level. This perhaps suggests that the academic achievement of moderate and high procrastinators is not different since the moderate procrastinators recorded a higher GPA than the high procrastinators.

Hypothesis 3: There will be no significant gender difference in the academic procrastination of the participants.

Table 4 shows that no gender difference exists in the procrastinatory behaviour between male and female. This is shown with t.obs = 0.19 > t.crit. 1.96 At 0.05 level and 148 degree of freedom. This implies that both male and participants exhibit the same level of academic procrastination, and this is affecting them accordingly.

DISCUSSION

Inspired by the need to improve student performance in mathematics courses, the purpose of this study was to determine if procrastination do affect students achievement in mathematics at the university level. The first hypothesis tested that there is no significant correlation between procrastination and mathematics achievement was not supported. In other words, the result indicated that there is a significant correlation between mathematics achievement and procrastination. The result of this study is supported by the findings of Beswick, Rothblum, and Mann (1986) which found that procrastination was correlated with low self-esteem and anxiety in high school students. Tice and Baumeister (1997) also reported that students who have strong tendencies to procrastinate tend to have low examination grades than non-procrastinators. The report by Popoola (2005), Wesley (1994), Beck, Koons and Migram (2000), and Tuckman, Abry, and Smith (2002) that procrastination is associated with poor academic achievement corroborate with the findings of the present study. The reason for lower academic performance of students who procrastinate might be due to their low levels of self-esteem and self-efficacy.

The result of the study also indicated that there is a significant difference between procrastination and mathematics achievement, with student with low procrastination having a higher achievement in mathematics than students with moderate and high levels of procrastination. This has a very significant implication for the quality and number of students that will be available for higher studies in the area of mathematics.

In an increasingly technological society, where knowledge of mathematics is needed to obtain a desired position in workforce, this means that students who procrastinate in the learning of mathematics are likely to limit their career choices to those that do not require mathematical skills. Going by the findings of Ellis and Knaus (1997) that ninety five percent of college students procrastinates; it becoming more serous in this age where mathematical knowledge are not only needed in scientific and technical fields but increasingly important in business, social sciences and even humanities.

The hypothesis that gender would have an effect on academic procrastination was not supported by the result. The result indicated that academic procrastination is independent of gender. This means that both male and female procrastinate in like manners. This corroborates the view of Ferrari and Beck (1998) that procrastination is no respecter of gender. Tuckman (1991) assert that procrastinators tend to describe themselves as people who doubt their capabilities and each gender unit have it own share of such people.

The levels of procrastination could also have been affected by the type of students' characteristics. Valadez (2006) have identified three types of students, as the unconcerned students, target- oriented students and passionate students. According to them, unconcerned students objective is that they just want to pass the class, look for easiest way, and are apathetic about studying. Such student exercise behaviours such as they does little studying or reading, look for help at the last minute, memorizes information, reproducing statements from source text, sometimes cheats ,and goofs in class. Indeed such students certainly do not take study seriously and may never pay attention to proper time management which is a source of academic procrastination.

The target-oriented student objectives are to get good grades and commit to reach that goal and exercise behaviours such as focusing on difficult tasks, do everything the instructors' wants, completes all assignments, manage time carefully, and gets help when needed. These types of students might have very low level of procrastination thereby performing well in their mathematical tasks or whatever tasks that comes their way.

The passionate student objectives are enthusiasm about learning for its own sake and exhibits behaviour such as focusing on the subject, reads widely, associates new ideas to previous knowledge, discusses the topic whenever possible, seek enlightment in other books and sources. This set of students will leave no stone unturned in their search for knowledge and thereby perform exceptionally well in their academic task. There is no room for procrastination in their daily work ethics.

When student manage time judiciously, taken time as precious commodity, periodically observing and modifying the use of it, procrastination may be reduced to the minimum. Such a student is likely to make sure that he/she is in the right class and have the proper prerequisites, and will be willing to review previous mathematics topics already forgotten which may be critical to the understanding of the new learning. In addition a student with low level of procrastination may also be involved in studying with classmate, teaching each other the principle involved and discussing difficult mathematics concepts, and reading the textbooks for additional information and examples. On the other hand, students with high levels of procrastination are not likely to take their studies seriously thereby engendering poor performance in mathematics grade. Since there is always not enough time to cover all aspects of a mathematics course in the classroom, procrastinators may not have the time to exert considerable effort outside of class to learn basic ideas about the subject matters from the textbooks. This invariably may lead to poor understanding of concepts, hence low mathematics grade.

Since procrastination isn't simply a habit, but complex pattern of recurring behaviours which includes emotions, thought, and actions and has becomes habitual to the procrastinator, getting rid of it will involve replacing, circumventing or deactivating each one of the habits by new habits (Wikibooks, 2006). Getting rid may not be that easy because a simply decision could easily be overwhelmed by the force of habit and such a decision need to be implemented as a habit itself before it can compete effectively with the old habit. For a student to be able to confronts and control his procrastinating behaviour the first stage is to look at self critically and determine the distractive and incompetence attributes that negates his positive behaviours towards his academic activities. Procrastination as a form of incompetence has to be eliminated in order to cure it. Since incompetence is the opposite or lack of competence, the only way to eliminate it is to be replaced with competence (Wikibooks, 2006). Personal competence is comprised of five elements: emotional strength, well-directed thought, time management skills, control over habits, and task completion abilities (Wikibooks, 2006). Improving on these personal competences is a surest ways of overcoming procrastination.

Some of the practical steps are for the students to be well organized by starting out small to accomplish the larger goal. In order words a student may need to prepare a scale of daily preferences dividing major projects which seems overwhelming into little pieces.

What is not getting done in one day can be added to the next day's list

Also a procrastinator may need to start with the easiest task and proceed from there to a more rigorous and demanding tasks. Success in the easier task is likely to motivate and ginger him to more difficult task and hence building up confidence in his ability to tackle academic matters. One of the major reasons why people avoid the very tasks that free them from mediocrity is their lack of self confidence (Plessis, 2006). A lack of confidence in one self according to (Plessis, 2006) will automatically keep one from those things which ordinarily one is capable of doing. Procrastination which is not just a device for avoiding mundane things but on a higher level, is avoiding the big decisions and big actions then set in and prevent one from making real difference in one's life.

REFERENCES

Agwagah and Usman (2002) .Training of undergraduate teachers in Nigerian Universities: Focus on problems of effective integration and attitude of students to computers in mathematics instruction. {Online}Available at http://www.math.uocgr/~ictm2/Proceeding/gap119pdf

Aitken, B (1982). *A Personality Profile of The College Students' Procrastination*. Unpublished Doctoral Dissertation, University of Pittsburgh.

Akinsola, M.K. & Tella, A. (2003).Effectiveness of individualistic and cooperative teaching strategies in learning geometry and problem solving in Mathematics among junior secondary schools in Nigeria. *Personality Study and Group Behaviuor* 23, 95-105.

Beck, B.L. & Koons, S.R, Migram, D.L. (2000).Correlates And Consequence of Behavioural Procrastination: The Effects of Academic Procrastination, Self-Consciousness, Self-Esteem, And Self-Handicapping. *Journal of Social Behaviour and Personality* 15, 3-13.

Beswick, G., Rothblum, E.D., and Mann, L. (1988). Psychological Antecedents to Student Procrastination. *Australian Psychologist*, 23: 207-217

Effert, B.R. & Ferrari, JR. (1989).Decisional procrastination, examining personality correlates. *Journal of Social Behaviour and Personality* 4,151-156.

Ellis, A. & Knaus, W.J. (2000).*Overcoming Procrastination*. New York: New American Library.

Ellis, A, &Knaus, W.J (1977).*Overcoming Procrastination*. New York. Institute for Rational Living.

Ferrari, J.R., &Beck, B.L. (1998).Affective responses before and after fraudulent excuses by academic procrastinator. *Education*, 118(4), 529-538.

Ferrari, J.R., & Emmons, R.A. (1995).Methods of procrastination and their relation to self-control and self-reinforcement: An exploratory study. *Journal of Social Behaviour and Personality* 10,135-142.

Ferrari, J.R., &Emmons, R.A. (1994).Procrastination as revenge: Do people report using delays as a strategy for vengeance? *Personality and Individual Differences* 17, 539-544.

Flet, G.Blankenstein, K.R., & Martin, T.R. (1995). Procrastination, negative self-evaluation, and stress in depression and anxiety: A review of preliminary model. In J.R Ferrari's, Johnson W.G & McCown (Eds). *Procrastination And Task Avoidance: Theory, Research, and Treatment* pp.137).New York; Plenum Press.

Jansenn, T. & Carton, J.S. (1999).The effects of locus of control and task difficulty on procrastination. *Journal of Genetic Psychology*, 160.

Lay, C. (1986).At last, my research article on procrastinator. *Education* 118(4), 529-538.

Learning Common s Fast facts Series (2004).Controlling procrastination. {Online}Available at http://www.learningcommons.uoguelph.ca (Accessed on 10th November, 2006).

Learning Common Fastfact Series (2004), Procrastination. Retrieved from http://www.learningcommons.uoguelph.ca/Fastfacts-Procrastination.pdf Accessed on15th July, 2006

Milgram, A.; Batin, B. & Mower, D. (1993).Correlates of academic procrastination. *Journal of School Psychology* 31,487-500.

Milgram, N.A. Dangour, W. &Raviv, A (1992).Situational and Personal determinants of academic procrastination. Journal of General Psychology 119, 123-133.

Noran, F.Y (2000).Procrastination among students in institutes of higher learning: Chalenges for K-Economy. Available at: http://www.mahdzan.com/papers/procrastinate/ Accessed on 17th November, 2006.

Oweini, A. & Harraty, N (2005).*The carrots or the stick: What motivate students?* A Manuscript. Lebanese American University. USA.

Plessis, D (2006). Self confidence, fear and the inevitable procrastination. Retrieved at http://www.self improvement-gym.com on 11th November 2006.

Popoola, B.I. (2005).A study of the relationship between procrastinatory behaviour and academic performance of undergraduate students in a Nigerian University. African Symposium: An Online Journal of Educational Research Network. Available at http://www2.

ncsu.edu/ncsu/aern/TAS5.1.htm (Accessed on 10th November, 2005).

Sirois, F.M. & Pychyl, T.A (2002).Academic procrastination: Cost health and well-being. Presentation at APA convention, August 22, 2002, Chicago, Illinois. Slides available at http://www.carleton.ca/~typcyl/prg/conferences/apa2002/apaslides2002/sld001.htm

Solomon, L.J. &Rothbluam, E.B. (1984).Academic procrastination: Frequency and Cognitive behavioural correlates. *Journal of Counselling Psychology* 31,503-509.

Tice, D.M, &Baumeister, R.F. (1997).Longitudinal study of procrastination, performance, stress and health: The costs and benefits of dawdling. *Psychological Science* 18,454-458.

Tuckman, B.W. (2003).The effects of learning and motivation strategies training on College Students' achievement. Journal of College Student Development,44 (3), 430-437.

Tuckman, B.W.; Abry, D.A. &Smith, D.R (2002).*Learning and motivation strategies: Your guide to success*. Upper Saddle River, N.J: Prentice-Hall.

Tuckman, B.W. (1991). The development and concurrent validity of the procrastination scale. *Educational and Psychological Measurement* 51(2), 473-480.

Tuckman, B.W. (1990).Group versus goal setting effects on the self-regulated performance of students differing in self-efficacy. *The Journal of Experimental Education* 58, 291-298.

Valdez (2006). Math study skills: 12 steps to success in math. Retrieved November 10 http://www.rock.uwc.edu/academics/trio/Math.pdf

Wesley, J. (1994).Effects of ability, high school achievement and procrastinatory behaviour on college performance. *Educational and Psychological Measurement* 54, 404-408.

Wikibooks (2006). *Overcoming Procrastination/Causes*. Retrieved from: http://en.wikibooks.org/wiki/Overcoming_Procrastination

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Trends and Challenges in Sport Science and Engineering Related Technology Education at Surf Science and Technology: Researching Surfboard Making Activity

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The paper presents the results obtained from teaching, learning and research associated with Surf Science and Technology (SST) course taught at the South West Campus of Edith Cowan University. The main topic discussed is Teaching and Learning with the Surfboard Making. It looks at a group of recent second year SST students who, after acquiring the necessary scientific and technological skills related to the production and performance of surfboards, were asked to design and produce their own surfboard during the Surf Equipment, Design, Materials and Construction Course. The first part of this paper describes briefly the most important steps in the surfboard making procedure. It is then followed by a series of photographs showing the SST students in various surfboard shaping and laminating activities. The next section provides some examples from teacher-student interactions in terms of individual approach and the group as a whole. It was realized that each student aimed to create a surfboard that would best suit his or her surfing skill. This resulted in the production of various surfboards that differed in the length, shape, weight, appearance, the number of fins, fin design and the surfboard/fin material. The results were analysed using a comparative statistical method that allowed determining the relative importance of each qualitative criterion with respect to other criteria associated with surfboard design features and performance. Following the discussion of the results, there are main conclusions highlighting the outcomes interesting from both pedagogical and professional practice perspectives.

Keywords: Technology education, surf science, surfboard design, performance, students' work

INTRODUCTION

There is a strong bond between surfers and their surfboards. Traditionally, the surfers are looking for any improvements in surfboards that would suit their style and enhance their surfing performance. Generally, the performance is dictated by the surfboard's geometrical features and materials and the ability of an individual to surf.

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Surfboard's Geometry and Materials: A brief history

Surfboards have been made for several hundred years. Some few rare 200-year old wooden surfboards are held at Honolulu's Bishop Museum (Kampion and Brown, 1997, p. 30). These earliest surfboards were, doubtless, of poor quality. History has indicated that the key technological improvements in surfboard constructions went through numerous trial-error-success experiments. According to source (Young and McGregor, 1983) some early Hawaiian long-boards produced around 1830's were made from 'hard' wood, were around 4.5m long and about 0.5m wide, and weighed approximately 50kg. Consequently, they provided good buoyancy but very low manoeuvrability. By the 1920's, Duke Kahanamoku had introduced long-board surfing to Australia and California (Young and McGregor, 1983; and That's Surfing, a History of Australian Surfing, 1999). The boards used at that time were made from soft-light balsa and were about 3 metres long. Their stability and turns were controlled by rails and foot drags, respectively. The rails were rounded and this geometrical feature was responsible for creating the sideway forces that were sufficient to keep the board on the wave (Hornung and Killen, 1976). According to another source (Australia's Surfing Life, 2005, p. 68), around 1930's an amateur surf equipment inventor Tom Blacke connected a boat keel to his surfboard and realised that by doing so he improved the stability. The keel acted as a fin and helped to hold the board in the water. Experiments with fins and surfboards continued. It was found that with a fin attached to the surfboard the rails can be square and sharp. In 1950's fibreglass and polyester resins forced their way into surfing industry. In 1960's the surfboards became to be produced from polyurethane foam blanks shaped and covered with water resistant fibreglass resin coat. Until mid 70's the trend was to have the sharp and 'hard' resin edges along the rails (Hornung and Killen, 1976). According to the same source (Hornung and Killen, 1976) those types of rails did not cope well with incident cross flow. A compromise was found by making the square 'hard' rails near the tail of the board to decrease the drag forces, and having more or less rounded rails further forward to the surfboard' nose to cope better with incident cross flow. Evolution continued with introduction of twin fin design at the end of 1970's and the three fin design (thruster) at the beginning of 1980's. The thruster became a very popular design and it is believed that about 90% (Australia's Surfing Life, 2005) of the world's boards are equipped with three fins.

There is a continuous evolution in surf science with respect to surfboards. Nowadays there are 5 main types of commercially made surfboard designs suited for different types of wave riding, namely Type "Fish" surfboards for small waves; Type "Short" – high performance- surfboards for bigger waves; Type "Mini-mal or Fun" surfboards for beginners; Type "Mal or Long" (Malibu) surf boards for small waves and easily paddling, and finally Type "Gun" for big wave riding. Source (Haines, Audy and Killen, 2004, p.37) suggested that the above boards vary in design, geometrical features and number of fins. Consequently each surfboard is a unique output of designers and shapers.

Currently the South West Campus Bunbury at the Edith Cowan University (ECU) has a number of young people studying, exploring and researching the scientific and technological aspects associated with the production and performance of surfboards. Over the course of several units the students are taught to understand materials, design features, quality management, standards and safety engineering. After acquiring the necessary skills, they are encouraged to design their own surfboard, shape it, manufacture it and test it. In an open learning environment they feel free to combine research science with hands-on skill and use their ideas. This approach produced a variety of different surfboards, examples of which are shown in the following section of this paper.

Surfboard Making Activity at ECU

Appendix 1 and 2 are sets of photographs showing various examples of students' work involved in surfboard making activity. These photographs are presented in a sequence that shows individual stages in a production flow charge. The photographs in Appendix 1 relate to the shaping process and they show the individual sub-operations and their role and tools used in producing the main surfboard design features. The photographs in Appendix 2 relate to the laminating process and they show a typical sequence of operations used in hand laminating of surfboards. The photographs were taken during the practical work in surf science shed in the second semester of 2004.

Each surfboard was designed in that way that it should provide a certain level of buoyancy for the surfer. Consequently, the board volume was closely related to the weight of a surfer. Moreover the surfing

Figure 1. Surfboards were born – we did it! Photo courtesy: Audy J., lecturer

style, height of a surfer and his or her preferences for a certain type of waves were other factors considered in surfboard making activity. Students selected the moulded blanks that had their design features similar to that of the final surfboards. The length, width and thickness of the moulded blank were chosen according to the height and weight of the surfer. Further design features, namely, the rocker, rails, bottom contours, nose shape, tails, and fins were chosen according to riding style and wave preferences of the surfer.

Students learned to design and make their surfboards from the scratch. The cost of an individual board produced at ECU was around $200 compared to the average of about $600 for commercial boards. Students clearly enjoyed the activities involved in surf-production and were happy with the results, see Figure 1.

RESULTS

Figure 2 depicts some of the SST students with their surfboards designed and produced in the second semester of 2005.

From Figure 2 it is evident that a number of different surfboards were produced by the ECU students. The most popular appeared to be the thruster *ie* three fin design, only one of those students produced a two fin design. Majority of these surfboards bore features similar to both a Type "Short", 4'0" to 6'3",

Figure 2. Some surfboards designed and produced at ECU in the Second Semester of 2004. Photo courtesy: Audy J., lecturer.

and a Type "Fish", 4'0" to 6'3", surfboards. One student designed a Type "Mini Gun" surfboard with the length of 6'6". Majority of students(~75%) got the templates from friends or shapers, other students (~10%) made templates for their surfboards by magnifying design features from 'as published' surfboard designs in various magazines, some students (~10%) copied the surfboard from an existing surfboard, and few students (~5%) calculated their surfboards for buoyancy. Students experimented with complex rail designs. Combinations varied from hard rails on tail for faster and less surface tension and soft rails from middle to nose for better manoeuvrability to high rails at nose, mid rails along middle and low rails along tail. The preferred tail shapes produced were swallowtail, pintail, round tail and squash tail. Moreover, the students showed a high level of art skill which is evident from the appearance of their surfboards. Therefore aesthetically nice looking surfboards seem to be of some interest. Finally, production took place between weeks 4 and 13 with most starting in weeks 5 or 6 thus the longest time taken for construction was about 9 weeks

In order to find out which criteria were important for our students when buying or making a surfboard, the students involved in surf-making activity were surveyed. The most important results are tabulated in Table 1. The results from this table indicated that mostly young people were interested in studying surf science and technology. Differences (±) in the height and weight indicated that the surfboards produced or purchased by those individuals would vary in length, width and thickness depending on the level of buoyancy needed by the surfer. Surfing activity was strong with 10 peoples surfing twice or more a week. It is expected that they must have also some surfing skill, and experience which would be useful for judging surfboard performance from an empirical point of view. When surveyed about surfboard ownership the average number of surfboards owned so far was 4 with the range of 9. The survey further indicated that the majority of students spent around $600 per surfboard. This indicated that the students opted to have more surfboards for less cost, and would change their surfboard when damaged or old.

The last part of this survey was focussed on the 'most important' criteria when purchasing a surf-board. These criteria were: craft cost, craft weight, craft shape, fin design, number of fins, craft durability, craft appearance, craft sharper, and fin/craft material. The results were statistically analysed in order to conduct a quantitative comparison of relative importance of various qualitative criteria with respect to each other. The results are presented and discussed from both qualitative and quantitative point of view in the following section

$$\%difference = \frac{100.(Criterion1 - Criterion2,3,4,...9)}{Criterion1} \qquad \textit{continue}$$

$$\%difference = \frac{100.(Criterion2 - Criterion1,3,4,...9)}{Criterion2} \qquad \textit{etc} \qquad \text{Equation 1}$$

e.g. $$\%difference = \frac{100.(CraftCost - CraftWeight)}{CraftCost} = \frac{100.(13-8)}{13} = 38.5$$

Table 1. The tabulated results associated with the survey conducted between the Surf Science and Technology Students at ECU in 2004.

PARTICIPANTS PERSONAL DETAILS	
Male	7
Female	8
Under 20 Years Old	9
Between 20-25 Years Old	4
Over 20 Years Old	2
Average height of males (cm)	175±5.5
Average weight of males (kg)	75±12.5
Average height of females (cm)	163±9.5
Average Height of females (kg)	57±8
MOST IMPORTANT CRITERIA WHEN BUYING A SURF-BOARD	
the craft weight	8
the craft cost	13
the craft design/shape	14
the fin design	6
the number of fins	5
the craft durability	3
the craft appearance	2
the shaper	1
the surfboard/fin material	1
SURFING ACTIVITY	
Never been surfing	0
Surfing once a week	4
Surfing twice a week	4
Surfing more than twice a week	6
SURF-BOARD(S) OWNERSHIP	
Do not have a surfboard	0
Own 1 surfboard	6
Have more than one and less than 3 surfboards	4
Own more than 3 surfboards	2
Average number of surfboards owned so far	4 min 1 max 10 (range 9)
Do not remember how many surfboards owned	2
COST OF THE SURF-BOARD PURCHASE	
around \$600	12
between \$600 and \$1000	3
more than \$1000	0
CHANGING THE SURF-BOARD	
Every six months	1
Once a year	1
When it's old or damaged	13

Statistical significance of each criterion against others was determined from the percentage difference between the two criteria that was calculated using Equation 1.

Whenever the percentage difference between two mutually compared variables was less than plus and/or minus 25% both criteria were considered to have the same level of statistical significance which was marked as 1. For percentage differences higher than positive 25% the first variable was more significant than the second variable. In such cases the statistical significance numbers were 2 and 0 for the first and second criterion, respectively. When percentage differences were more negative than negative 25% then the first variable was less significant than the second variable. In such cases the statistical significance numbers were 0 and 2 for the first and second criterion, respectively. An example of determining statistical significance of the craft cost criterion against the other eight criteria, namely craft weight, craft shape, fin design ….. craft/fin material, is shown in the following Table 2.

The same approach was used to calculate the percentage difference(s) and statistical significance coefficient(s) for all possible criterion to criterion combinations. The qualitative criteria and their corresponding significance coefficients are tabulated in Tables 3.
For each criterion (1 … i … 9), in Table 3 the relative quantitative importance (q_i) was calculated using Equation 2.

$$q_i = \frac{D_i}{\sum D_i} = \frac{D_i}{D} \qquad \text{Equation 2}$$

In Equation 2, the D_i represents the individual quantitative pointer for each qualitative criterion, and was calculated as a sum of statistical significance numbers in a row *e.g.* for craft weight criterion had D_i=11 *i.e* (0+0+2+2+2+1+2+2). The D represents the statistical sum quantitative pointer of all D_i values for the whole sample set. The sum of relative quantitative importance (q_i) values should be equal to 1 for overriding importance/significance.

Table 2. A key to determine statistical significance of one criterion against other criteria

Craft Cost versus	Craft Weight	Craft Shape	Fin Design	Number of Fins	Craft Durability	Craft Appearance	Craft Sharper	Craft/Fin Material
13	**8**	**14**	**6**	**5**	**3**	**2**	**1**	**1**
% difference	38	-8	54	62	77	85	92	92
Significance of Craft Cost versus	**2**	**1**	**2**	**2**	**2**	**2**	**2**	**2**

Table 3. Statistical results showing the perceived relative importance, qi, for variety of qualitative criteria, calculated from responses of the 2nd year students involved in surf-making activity.

	Craft Weight	Craft Cost	Craft Shape	Craft Durability	Craft Appearance	Craft Shaper	Fin Designs	Number of Fins	Craft / Fin Material	D_i	q_i
Craft Weight	---	0	0	2	2	2	1	2	2	11	0.152
Craft Cost	2	--	1	2	2	2	2	2	2	15	0.208
Craft Shape	2	1	--	2	2	2	2	2	2	15	0.208
Craft Durability	0	0	0	-----	2	2	0	0	2	6	0.803
Craft Appearance	0	0	0	0	-----	2	0	0	2	4	0.055
Craft Shaper	0	0	0	0	0	---	0	0	1	1	0.014
Fin Designs	1	0	0	2	2	2	----	1	2	10	0.138
Number of Fins	0	0	0	2	2	2	1	----	2	9	0.125
Craft /Fin Material	0	0	0	0	0	1	0	0	----	1	0.014

To determine the quantitative importance of each qualitative criterion in the sample group the qualitative criteria were rearranged in order from highest to lowest relative quantitative importance according to their q_i values, see Figure 3.

DISCUSSION

From Figure 3 it is evident that for this group of students the most important factors were the craft cost and craft shape (both with q_i=0.208). Other important factors were craft weight (q_i=0.152), fin design (q_i=0.138), and number of fins (q_i=0.125). Less important factors were craft durability (q_i=0.083) and craft appearance (q_i=0.055). Surprisingly the criteria associated with the craft shapers and craft fin material had very low importance factor (*ie* q_i=0.014). From this analysis one can deduce the following: The economical importance of purchasing the surfboards became more evident when 80% of respondents indicated that they are willing to spend around $600 or less for the surfboard(s), and that 87% of them would change their surfboard(s) only when old or damaged, see data in Table 1. This shows that all improvements in surfboard construction that are currently sought through the changes in design and materials should not exceed the $600 level for the surfboards to be sold, and hence be able to compete, successfully in open market. Craft shape was appreciated as functional variable that influence the performance of the surfboards. The craft weight was supported by 53% of respondents. The current trend in surfboard production is to reduce the craft weight as much as possible. However, this feature is not isolated from others. It affects mechanical

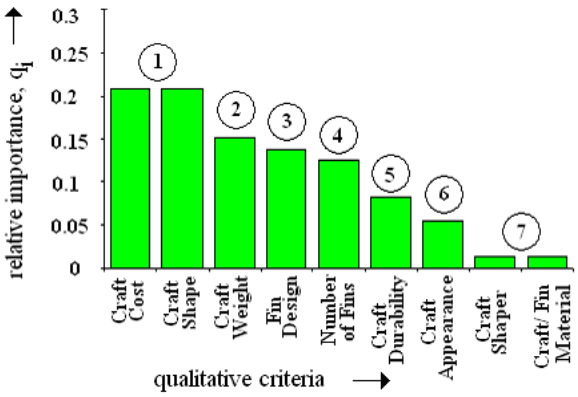

Figure 3. Histogram showing a relationship between the relative importance values and qualitative criteria with reference to data in Table 3.

properties of surfboards, so when surfing, strange things can happen. Boards break where they should not, mostly because of their inability to deal with wave impact forces due to reduced strength, stiffness and toughness. Generally, reductions in the weight are sought via reductions in surfboard thickness features. This approach however reduces both strength and durability.

There are some possibilities to reduce the craft weight by reducing the number of fibreglass layers, and squeezing resin off the cloth when embalming the foam core, but the penalty is reduction in stiffness. Stiffness can be improved by replacing the common E-fibre glass with carbon fibres but the penalty is increased cost. It is therefore evident that the choice of correct material(s) is critical and requires a full understanding of all the interactive factors. It is recognized from experience that the qualitative level of the whole surfboard is ultimately dependent upon the level of the weakest – most inadequate – part of the total product which can be any variable in material and design features. To maximize quality the whole quantities have to be lifted to a similar level. This level, however, has to be economically sound. In contrast, the recent survey has shown that our students have a tendency to underestimate the role of materials in surf board production since the craft/fin material criterion was ranked at the tail of group order similarly as craft shaper.

The fact that the craft shaper criterion had very low impact factor (q_i=0.014) indicates that it does not matter who shapes the board unless the craft has the right shape and appearance. Finally the survey results showed that the number of fins was a highly sought surfboard feature (q_i=0.125), supported by 34% of respondents.

These respondents probably prefer the three fin design (known as thruster) invented by Simon Anderson in early 1980's.

According to our statistical results the number of fins was almost as important as the fin design see group order numbers 5 (q_i=0.125) and 4 (q_i=0.138), in Figure 5. However, the increases in fin numbers would result in increases of the craft weight, unless other improvements are done via fin design and fin materials. Thus, it is apparent that a surfboard that has to be treated as a complex system with mutual interrelationship between its various qualitative and quantitative measures. Consequently, there is a need to gain a deeper understanding of potential of various manufacturing procedures and materials may have on improvement of design and performance of surfboards.

CONCLUSIONS

Conclusions that can be drawn from this study are summarised as follows: The authors were granted a "Teaching and Learning" grant which was used to support the surfboard making activities.

The students responded well and enthusiastically to the laboratory work because:

1. they were able to design their own surfboard that would suit best to their surfing style and ability.
2. they learned about shaping and laminating procedures relevant to those used in real industrial production.
3. they were able to use their results from other SST units lectured by the same lecturer to improve the design of their surfboard.

Type Short (three fin – thrusters) were the most produced surfboards. One student made a type two fin short board. One student made a type 'mini' gun surfboard. All the surfboards had complex rail design. Hard rails were preferred on tail and soft rails from middle to nose. Few boards were designed to have high rails at nose, mid rails along the middle and low rails at tail. Type swallowtail appeared to be the most preferred tail shape. The manufacturing cost was ~$200 which was substantially less than ~$600 for average priced commercial surfboards. The shortest and the longest time taken for the surfboard construction were 2 weeks and 9 weeks respectively.

It was recognised that for purchasing or designing a surfboard it is necessary to consider the following criteria: craft weight, craft cost, craft design/shape, fin design, number of fins, craft durability, craft appearance, sharper, surfboard / fin materials. These criteria were found to be mutually linked to each other and cannot be treated separately if the surfboard is to be evaluated as a whole system. Our study showed that a variety of literature sources refer to above criteria in rather descriptive and qualitative way, and provide very limited or no quantities for quantitative comparison.

Consequently the SST students - those involved in surfboard production - were surveyed and the results were statistically analysed. This approach helped to finalise on scientific base a final order in importance of criteria that were used by our SST students for purchasing or building a 'best-fit' surfboard. This order, from best to worst, was: Craft Shape and Craft Cost, 1 (q_i=0.208), Craft Weight, 2 (q_i=0.152), Fin Design, 3 (q_i=0.138), Number of Fins, 4 (q_i=0.125), Craft Durability, 5 (q_i=0.083), Craft Appearance, 6 (q_i=0.055), and Craft Shaper and Craft/Fin Material, 7 (q_i=0.014). This indicated some underestimation of effects of materials (q_i=0.014) against other, higher ranked criteria. Consequently, more work is needed to study potential of various manufacturing procedures, materials and design features that may improve the performance of surfboards.

REFERENCES

Australia's Surfing Life. (2005). 'Asl's mighty summer 2005 board bible'. [Brochure], Australia, p. 68.

Haines, T., Audy, J., Audy, K., and Killen P. (2004). Incorporation of Novel Ideas into 'Surf Equipment, Design, Materials and Construction' Course. In New Challenges for Sustainability and Growth in Higher Education (pp. 36-47), [CD]. Perth, WA: Edith Cowan University.

Hornung, H.G., and Killen, P. (1976) A Stationary Oblique Breaking Wave for Laboratory Testing of Surfboards. *Journal of Fluid Mechanics* 78, 458-480.

Kampion, D., and Brown, B. A. (1998) *History of Surf Culture*, Spain: General Publishing Group Inc.

That's Surfing, A History of Australian Surfing, [Video]. Melbourne: Visual Entertainment Group Pty Ltd.

Young, N., and McGregor, G. A (1983) *The History of Surfing*, Australia: Palm Beach Press - Deaton and Spencer Pty. Limited.

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Appendix 1. Photographs showing the production sequences of shaping procedures for various surfboards. Photo courtesy: Audy J. – lecturer.

(a) Drawing the shape of the surfboard on one side of the blank.

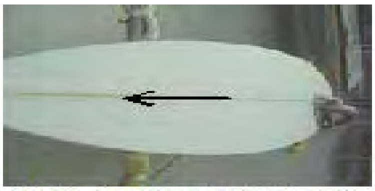
(b) Cutting the shape.

(c) Cutting and trimming the tail and nose.

(d) Using a sur-form to plane the shape

(e) Using a cardboard paper to make a template of the planed shape. Offsetting it along the stringer.

(f) Repeating the procedures (2) and (4) to get the rough shape of your surfboard.



(g) Using an electric planner to cut off the rough skin from the bottom part of the blank

(h) Using a sur-form to sand off the bottom part of the blank.

(i) Foam is softer than wood, hence occasionally we need to use a spoke shave to plane the stringer.

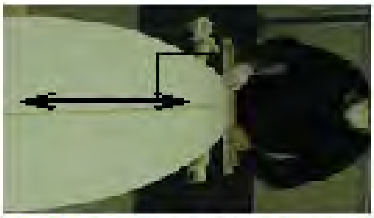
(j) Using an electric planner to produce a 'rough' shape of the tail kick

(k) Using an electric planner to produce a 'rough' shape of the nose kick

(l) When making the tail kick and nose kick the sequence of cuts should follow that pictured above. Note that the direction of cuts is along the stringer

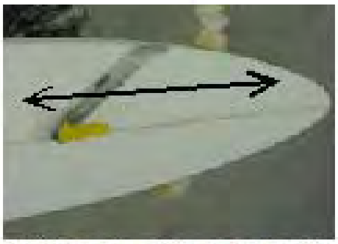
Appendix 1 Continued from previous page

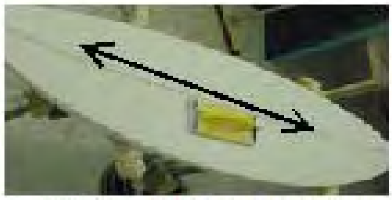

(m) Using a fine sand paper for sanding off the bottom part of the blank


1(n) Using a piece of wood covered in a sand paper making the smooth bottom plane


(o) With the deck facing up using an electric planner for cutting off the rough skin.

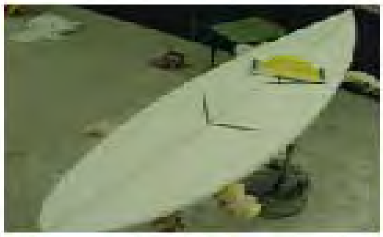

(p) Using an electric planner for cutting off the rough skin from the nose of the blank


(r) Using a sur-form planer for sanding off the deck; and using a spoke shave to plane the stringer whenever needed.


(s) Using a fine sand paper for finishing the deck; and using a spoke shave to plane the stringer whenever needed

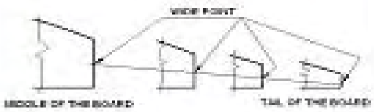

(t) Drawing the line representing the thickness of the surfboard then placing the surfboard by its top side up and shaping the deck


(u) Using an electric planer for creating the rough contours when shaping the deck

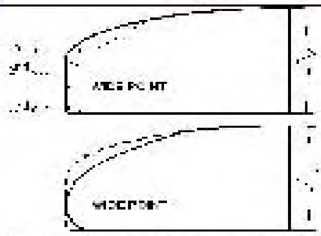

(v) Smoothening the deck with sand paper.

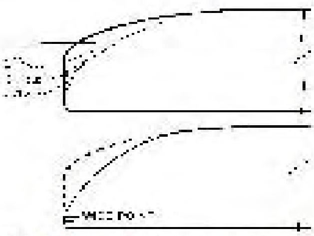

(w) When shaping the deck it is necessary to make long continuous movements with a hand that holds the shaping tool and check possible bumps with another hand.


(x) Drawing the lines representing the dimensional features of surfboard rail(s).



(y) Trimming the edges using surf-form planer and/or sand paper planer


(z) This picture shows a process of shaping the rails along the middle part of the board.


(q) This picture shows a process of shaping the rails along the tail of the board.


(aa) Shaping the rails step by step side by side is needed in order to keep the symmetry.


(bb) Using a shaping gauge *is 'shapow shit'* the edges of rails are rounded and trimmed.

Appendix 1 Continued from previous page

(cc) Long gentle movements with rounded gauge are used to make the rounded rails.

(dd) when doing tail it is necessary to have the rounded edges at the top, but the bottom must stay sharp.

(ee) Misery likes company if the foam is chipped during shaping there is no need for panic

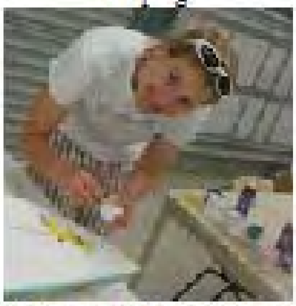
(ff) Q-cells mixed with resin will do the job

(gg) Q-cells will help to fix the cracks and fill-up the missing parts

(hh) When the shaped blank is shaped, the off-cuts represent about 30% of the blank weight before shaping.

(ii) The shaped blank is ready for decorating

(jj) Here it will be the cranium in helmet



(kk) Here it will be a little duck

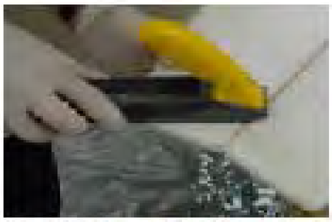
Appendix 2. Photographs showing the production sequences and tools used in hand laminating procedure of various surfboards. Photo courtesy: Audy J. – lecturer.

(a) Board is placed on the rack, and its bottom part is covered with a piece of cloth. The cloth is cut with about 2.5cm of excess on each end

(b) Tail and nose sections are V-notched for avoiding the cloth to buckle when lapping it underneath

(c) Catalysed resin is poured on the centre of the board and the cloth is fully wetted d.

(d) Squeegee is used to spread the resin over the cloth until it is fully wet and then overhanging cloth is lapped underneath and excess resin is removed



(e) Laminating resin stays tacky and is unsandable so sur-form is used to smoothen the rough surfaces

(f) For deck laminating in some cases we used 2 cloths. Here the top layer was 135gsm cloth, and the bottom layer was 190gsm cloth in order to increase the strength

(b) Cloth was cut with about 2.5cm of excess on each end and the tail and nose sections were V-notched.

(g) Procedure for deck laminating was similar to that described in (c) and (d)

(h) Overhanging wet cloth was lapped with squeegee underneath

(i) Sur-form was used to smoothen the rough surfaces

(k) Masking tape was applied to the rails and the bottom part was covered with catalysed filler resin

After about 10 minutes (before resin fully cured) the masking tape was removed. The board was let to fully dry and the procedure was repeated on another side of the board.

Appendix 2 Continued from previous page


(l) Catalysed filler resin is sanding resin was applying on deck, left, and bottom part , right, of the surfboards

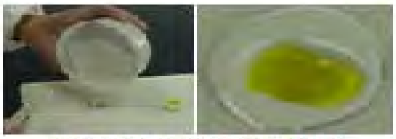

(m) The board was inspected


(n) The resin was sanded usi sanding machine


(o) or manually


(p) The board was inspected


(r) Hole for rope plug was dr


(s) Q-cells were mixed with catalysed resin and the rope plug was fixed in the hole


(t) Fins were positioned on the board


(u) Cloth strips were cut, catalysed resin was prepared and fins were laminated to the board. Masking tape was used to protect the surfboards from resin excess.


(v) Fins were covered with sanding resin


(w) After drying the fins were sanded


(x) Situating plugs for removable fins


(y) Drilling holes for the plugs for removable fins

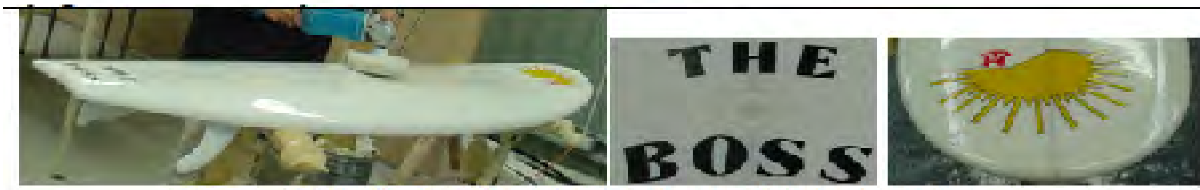

(z) Plugs were fixed in their holes using a mixture of Q-cells, short fibreglass strips and laminating resin


(q) The excess resin was removed and the surface smoothened.


(aa) The fins were fitted into the plugs to check their final position


(bb) Hard resin edges were made on some surfboards

Then the whole surface of the surfboards was wet sanded by hand firstly using 400 grid and then 600 grid silicon carbide sand paper.



(cc) Finally the surface of surfboards was polished and waxed

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Reflection and Remarks on the Conversation "The Past, Present and Future of the Nature of Science Research" with Norman Lederman

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Received 09 October 2007; accepted 23 November 2007

The conversation between myself and Professor Lederman took place in Malmö, Sweden on August 25, 2007. The purpose of the conversation was to elaborate on the past, present and future of nature of science research and also to provide insights for beginning researchers. In this text I am providing the questions about which we talked and my reflections based on my own experience together with some elaborating remarks from the science history.

Keywords: Nature of Science, Science History, Testing Assumptions

INTRODUCTION

Dr. Norman G. Lederman is currently Chair and Professor of Mathematics and Science Education at the Illinois Institute of Technology. He has taught a full range of graduate (Masters and Doctoral) courses in secondary science education and supervised teaching interns. Dr. Lederman received his Ph.D. in Science Education from Syracuse University (1983); M.S. in Secondary Education from Bradley University (1977); M.S. in Biology from New York University (1973); B.S. in Biology from Bradley University (1971).

Before arriving at his present position, he was Professor of Science and Mathematics Education at Oregon State University since1985, Assistant Professor of Teacher Education, SUNY/Albany (1984-85) and Assistant Professor of Science Teaching, Syracuse University (1983-84). Dr. Lederman taught high school biology as well as college level biology for many years. Throughout the years he has received several awards and recognitions for his teaching and research.

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Dr. Lederman is internationally known for his research and scholarship on the development of students' and teachers' conceptions of nature of science and scientific inquiry. He has also studied preservice and inservice teachers' knowledge structures of subject matter and pedagogy, pedagogical content knowledge, and teachers' concerns and beliefs. Dr. Lederman has been author or editor of 10 books, including an elementary science teaching methods textbook. Recently he co-edited "The Handbook for Research in Science Education." He has written 15 book chapters and published over 170 articles in professional refereed journals. In addition, Dr. Lederman has made over 500 presentations at professional conferences and meetings around the world. In the 2007 ESERA Conference he delivered a keynote speech entitled "Science Education as a Discipline: Does Our Research Meet Our Aspirations?"

Dr. Lederman has served in different capacities in professional organizations as member of board of directors, division director, regional director, etc. Most notably, he has also served as President of the National Association for Research in Science Teaching (NARST), the Association for the Education of Teachers in Science (AETS), and the Oregon Educational Research Association. Dr. Lederman is presently the Editor of the journal *School Science and Mathematics* and serves, or has served on the Editorial Boards of the Editorial Boards of many international academic journals in our field including Science Education; Journal of Research in Science Teaching; International Journal of Science Education; Journal of Science Teacher Education; Science and Education; and Eurasia Journal of Mathematics, Science and Technology Education.

Below you will find some snapshots of our conversation and my reflection and remarks on selected issues that we discussed. During our conversation I directed several questions to Professor Lederman. For the record they were the followings:

- What marked the beginning of interest and research in nature of science as far as science educators are concerned?
- What elements of nature of science did the early researchers consider?
- How was the gender issue in the early times? For teaching kids for becoming a scientist, do you think that both genders were encouraged equally?
- How did the NOS research evolve during the past several decades and what role do you think you played in it?
- Are you happy with the current status of nature of science research? That is, did we come a long way and what was it like?
- Today, do you think the NOS research draws attention that is deserves?
- How do you see the future of the nature of science research?
- How do you see the international contribution from other geographical regions and cultures to NOS research?
- What suggestions do you have especially for young researchers? And for starters of nature of science research, what would you recommend?

Reflection

One of my questions was about the gender equity problem in science education and for preparing future scientists. Professor Lederman gave examples of unfair treatment that he came to know. Surely there exist positive examples as well. We hope that the situation is getting better around the world with the growing awareness and concerns. As to the situation in Turkey, both in the past and today, I cannot say that it is perfect. However, it can be stated here that today according to a report[1] on women's employment in Turkey the percentage of women employed at Turkish universities is 36% and they comprise one fourth of all professors. Also, women have a 31% representation among architects and 29% among medical doctors and surgeons in Turkey. Moreover, in 2004 50% of doctorates were awarded to women in Turkey (OECD, 2007, p.43). These figures, although by no means satisfactory, might show a better status for woman as compared to many countries, including the developed ones. However, it should be noted that problems and cases of the type mentioned in the conversation are also visible in Turkey.

The types of contributions to a body of literature may come through different paths. A path could be via expanding the scope of the literature (theory) either by broadening or deepening it. Adding new and novel instances of an observed (known) phenomenon and explaining how they fit in a theory can be beneficial[2]. On the other hand, one can try innovative and original methods to the cases even if they were researched by other methods before. Conversely, existing methodologies can be applied on different or unusual samples that have never been researched until now. In this sense Professor Lederman and his group contributed to the nature of science research by creating pioneering assessment techniques (see Lederman, Wade and Bell (2000) for a review in this area). To this end, I can also add my own contribution (Tasar, 2006a; 2006b) to the nature of science literature: assessing prospective teachers' understanding of tentativeness in science by using scientific vignettes[3]. In this work I utilized a piece published in the National Geographic magazine (Newman, 2005) in which a present-day story was told about how and why two scientists were disagreeing on a subject (i.e. the reason for toxicity of the fugu fish). The results showed that this could be a fruitful method of probing participants' understandings and their ways of reasoning about nature of scientific knowledge. Now this line of research can be further expanded in two different ways: first, by using the same vignette to probe understandings of different samples (e.g. younger pupils, in-service teachers, etc.); second, creating new vignettes that can be utilized in probing different aspects of nature of science and scientific knowledge.

Professor Lederman very rightfully indicated in our conversation that developing an expertise in a field requires a lot of hard work within a narrow area and one cannot become an expert on everything. He also stressed the need for a focus in researchers' scope. Science education is a broad area within itself too. Even when we think of the nature of science literature we can find several threads in there. For example, I tried to locate my dissertation study within the science

[1] http://www.kssgm.gov.tr/istihdam.html

[2] See for example Little (1964). The first three sentences of the abstract are as follows: "London's idea that superconductivity might occur in organic macromolocules is examined in the light of the BCS theory of superconductivity. It is shown that the criterion for the occurence of such a state can be met in certain organic polymers. A particular example is considered in detail."

[3] It should be noted here that this type of vignettes are different than the interactive historical vignettes which were created and used by Wandersee and Roach (1998).

education literature by giving a brief summary of the science education research in the first chapter. I also tried to show how my focus in the dissertation was related to the bigger ideas (Tasar, 2001, p. 6). Although, other classifications may exist (e.g. Duit, 2007) I divided the major research areas in science education into six categories: the nature of content area and subject matter, the nature of science and scientific knowledge, the nature of teachers and learners, the nature of teacher training, the nature of teaching and learning, the nature of teaching and learning environments (Tasar, 2001, p.3).

When I began my doctoral studies I was a complete stranger to the field. At that point in time the only relevant journal I knew was, as a physicist by training, the American Journal of Physics which in addition to physics papers also publishes physics teachers' and professors' own work about teaching and learning physics. Hence the very first paper I read was teaching mechanics at high school level (i.e. Wells, Hestenes and Swackhamer, 1995). As a rookie, I was real worried about being in that situation and did not even know where to begin. I only hoped that things would unfold by themselves. But I did one thing right: I read a lot about my own field, which is physics education. Soon I discovered all the major journals in the field and very often when I went to the library inspected each of the past volumes and issues. Another thing I did right was when I was reading a paper, I carefully examined the given references and tried to obtain and collect the ones that I saw referenced often in the works that I read or thought were important. In this way I tried to close the gap in my readings since I wanted to develop a good knowledge of the existing literature base. I picked a few major topics as my areas of interest during my doctoral studies: physics education (mainly teaching and learning of topics in mechanics), philosophy of science (the history and nature of science), and cognitive basis of learning. Later, these became my supporting areas during my doctoral studies and I grouped the courses I took under these topics.

Whenever I asked my doctoral adviser Professor Vincent Lunetta about what I would do for my dissertation he always non-hesitantly replied: "something you can do and something worth to do." This was very frustrating indeed. It happens at times that a doctoral student suddenly becomes a part of a research project which I think the case for many engineering or science studies. When a graduate student enters a lab with the director of the lab being her/his advisor, then most things concerning the candidate's future research are readily set. With an ongoing research project the new recruit is somehow fit into a part of it. What is expected of her/him is not to do a separate work, but rather to complete a definite part of the puzzle in hand. However, if the grad student has to identify a problem and a set of research questions in an area, things don't come very easily. But one should always keep in mind that 'good things come to those who wait for them with patience and perseverance; but the rushing and impatient ones will go from trouble to trouble.' Likewise, expertise does not develop overnight by itself and one cannot figure out immediately a viable and worthy set of research questions to pursue.

Remarks

Professor Lederman also draws attention to "testing assumptions" that still exist in the literature as possible areas for extension and improvement. One of such assumptions he mentioned from education was the taken for granted linear relationship between teachers' and students' knowledge. An example of this sort of scientific activity can also be seen in James D. Watson's Double Helix:

> "Conversations with Cavalli, nonetheless, hinted that Joshua was not yet prepared to think simply. He liked the classical genetic assumption that male and female cells contributed equal amounts of genetic material, even though the resulting analysis was perversely complex. In contrast, Bill's reasoning started from the seemingly arbitrary hypothesis that only a fraction of the male chromosomal material enters the female cell. Given this assumption, further reasoning was infinitely simpler.
>
> As soon as I returned to Cambridge, I beelined out to the library containing the journals to which Joshua had sent his recent work. To my delight I made sense of almost all the previously bewildering genetic crosses. A few matings still were explicable, but, even so, the vast masses of data now falling into place made me certain that we were on the right track. Particularly pleasing was the possibility that Joshua might be so stuck on his classical way of thinking that I would accomplish the unbelievable feat of beating him to the correct interpretation of his own experiments." (p.92)

A success story that involves testing a prevailing assumption is that of Alex Müller and Georg Bednorz, researchers at the IBM Research Laboratory in Rüschlikon, Switzerland then in 1986. They made a truly breakthrough discovery in the field of superconductivity by creating a brittle ceramic compound (containing lanthanum, barium, copper and oxygen) that showed an unexpectedly high transition temperature into the superconducting phase (until then the highest transition temperature was observed in Nb_3Ge at 23.3 K and the new ceramic compound exhibited a transition temperature at around 30 K which was an astonishingly high temperature to show a superconducting property for any known substance at the time). The reason for Bednorz and Müller's discovery for being so remarkable is the fact that ceramics are normally insulators. At normal temperatures materials of this type do not conduct electricity well at all. So, researchers until that time had not considered this class of materials as possible candidates for superconductivity and as a consequence did not study such materials. However, by synthesizing and testing the electrical properties of these materials known as cuprates

In their lecture delivered on the occasion of the presentation of the 1987 Nobel Prize in Physics Bednorz and Müller (1988) explain in detail the path they followed which eventually led to the prize. In that lecture they also openly state that they tested the idea of producing superconductivity in non-metallic substances (i.e. oxides) with the following words:

> "And indeed, for somebody not directly involved in pushing T_c's to the limit and having a background in the physics of oxides, casual observation of the development of the increase of superconducting transition temperatures, shown in Fig. 1, would naturally lead to the conviction that intermetallic compounds should not be pursued any further. This because since 1973 the highest T_c of 23.3 K (Muller, 1980; Beasley and Geballe, 1984) could not be raised. But nevertheless, the fact that superconductivity had been observed in several complex oxides evoked our special interest. (…)
>
> Since the publication on the existence of this new class of materials, the interest and work have far exceeded the expectations of the laureates, whose aim was primarily to show that oxides could "do better" in superconductivity than metals and alloys. Due to this frenzy, progress on the experimental side has been rapid and is expected to continue."

Vitaly Ginzburg is one of the physicists who worked in the field of superconductivity for so long and contributed to our understanding of the phenomenon so immensely. He also draws attention (Ginzburg, 2004) to testing assumptions in his 2003 Nobel lecture in physics. Let's read:

> "The following fact serves to illustrate the accidental, to a certain extent, character of the discovery of high-temperature superconductivity. As far back as 1979, in one of the institutes in Moscow they produced and investigated (Shaplygin *et al.*, 1979) a $La_{1.8}Sr_{0.2}CuO_4$ ceramic, which was close to that investigated by Bednorz and Muller, with $T_c \approx 36$ K (Cava *et al.*, 1987). However, Shaplygin *et al.* (1979) measured the resistance of their samples at temperatures not lower than the liquid-nitrogen temperature and therefore did not discover their superconductivity. From the above one may draw a trivial conclusion that all newly produced materials should be tested for superconductivity. Also evident is another conclusion, namely, that even today it is possible to make a major discovery and next year be awarded a Nobel Prize for it without gigantic facilities and the work of a large group. This should be a source of inspiration, particularly for young people."

It is indeed worth testing the assumptions we have and, in my opinion, the beginning researchers are and should be more inclined to do so since the old guns usually have a predetermined mind set or prefer to give way to testing assumptions to beginners perhaps since they think no desired result is likely to be produced in such an endeavor.

Professor Lederman has contributed to the field enormously in different capacities during his carrier as a professor and researcher and brought his insights to the conversation as well. Overall, I believe that our conversation has important clues for researcher especially for the beginning.

REFERENCES

Bednorz, J.G. and Müller, K.A. (1988). Perovskite-type oxides – The new approach to the high-T_c superconductivity. *Reviews of Modern Physics*, 60(3), 585-600.

Duit, R. (2007). Science Education Research Internationally: Conceptions, Research Methods, Domains of Research. *Eurasia J. Math., Sci. & Tech. Ed.*, 3(1), 3-15.

Ginzburg, V. L. (2004). Nobel Lecture: On superconductivity and superfluidity (what I have and have not managed to do) as well as on the "physical minimum" at the beginning of the XXI century. *Reviews of Modern Physics*, 76(3), 981-998.

Lederman, N.G., Wade, P. & Bell, R.L. (2002). Assessing understanding of the nature of science. In McComas, W.F. (Ed.) *The nature of science in science education - Rationales and strategies* (pp. 331-350). Kluwer Academic Publishers: Dordrecht, The Netherlands.

Little, W. A. (1964). Possibility of Synthesizing an Organic Superconductor. *Phys. Rev.,* 134(6A), A1416-A1424.

Newman, C. (2005). 12 Toxic Tales - A delicacy to die for "5". *National Geographic*, 207(5), 17.

OECD (2007). *OECD Science, Technology and Industry Scoreboard 2007 -Innovation and Performance in the Global Economy.* OECD Publishing: Paris, Fransa.

Tasar, M. F. (2001). *A case study of a novice college student's alternative framework and learning of force and motion.* Unpublished doctoral dissertation, The Pennsylvania State University, University Park, PA.

Tasar, M. F. (2006a). Probing preservice teachers' understandings of scientific knowledge by using a vignette in conjunction with a paper and pencil test. *Eurasia Journal of Mathematics, Science and Technology Education,* 2(1), 53-70.

Tasar, M. F. (2006b). *Portraying and understanding the relationship between theory and scientific law.* Paper Presented at NAESA 2006 – Joint North American European and South American Symposium: Science and Technology Literacy in the 21st Century, University of Cyprus (31 May- 4 June, 2006).

Wandersee, J. H., & Roach, L. E. (1998). Interactive Historical Vignettes. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding* (pp. 281-306). San Diego, CA: Academic Press.

Watson, J.D. (1969). The Double Helix: A Personal Account of the Discovery of the Structure of DNA. New York: Mentor.

Wells, M., Hestenes, D. and Swackhamer, G. (1995). A Modeling Method for High School Physics Instruction, *Am. J. Phys.* **63**: 606-619.

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Book Reviews

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THE ANALOGICAL MIND: PERSPECTIVES FROM COGNITIVE SCIENCE

Edited by Dedre Gentner, Keith J. Holyoak and Boicho N. Kokinov
2001
A Bradford Book, the MIT Press, Cambridge, Massachusetts
520 pp.
ISBN 0-262-07206-8 (cloth)

'…Gilgamesh covered

Enkidu's face with a veil like the veil of a bride.

He hovered like an eagle over the body,

or as a lioness does over her brood'.

(Gilgamesh, 2000 BC, cited in Holyoak, Gentner & Kokinov, chapter 1, p. 4).

A 13-month-old infant, not yet capable of speech, watches an adult retrieve an out of reach doll by removing a barrier and pulling a string attached to the toy's foot. Following this demonstration, the child is able to retrieve another out-of-reach toy for herself.

(Chen, Campbell & Polley, 1995, cited in Goswami, chapter 13)

What does the description of the Mesopotamian hero-king have in common with the infant's actions? Each involve analogical reasoning; the ability to think about relational patterns. The comparison between Gilgamesh and the lioness is not a literal one; we are not asked to believe the King's appearance resembles that of a lioness. Instead we are asked to draw a structural comparison; it is his vigilance over his friends' corpse that we are asked to compare to a lioness' watch over her cubs. The modern day infant performs a similar feat of reasoning. In solving the novel problem for herself she must ignore superficial differences between the model's actions and her own. She must concentrate instead on the structural similarities between the two problems; the causal relations which can be transferred from one problem to another (Goswami, chapter 13).

This edited volume describes the 'state of the art' in analogy research. The editors, Gentner, Holyoak and Kokinov, have been at the forefront of analogy research for over twenty years. In this volume they combine their expertise with that of researchers from diverse disciplines; exploring the role of analogy in decision making (chapter 11), emotional inferences (chapter 10), metaphor (chapter 6), education (chapter 12) and politics (chapter 9).

The two examples quoted above, the ancient poem and the infant's actions, hint at the significance of analogical reasoning for general cognition. Analogical reasoning appears in our earliest preserved literature (Holyoak, Gentner & Kokinov, chapter 1) and we demonstrate the skill, in a rudimentary form, from early childhood (Goswami, chapter 13). The centrality of analogy to cognition is a theme developed throughout this volume. Analogy, is, according to Hoftsadter (chapter 15), 'the lifeblood…of human thinking'. It is the means through which we form basic categories such as 'same' and 'different' as well as more sophisticated ones like 'helicopter' and 'ethnic cleansing'.

Despite the immense significance of analogy for human cognition, a third example from the book

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suggests that analogy is not a uniquely human skill. Oden, Thompson and Premark (chapter 14) present evidence that Sarah, a chimpanzee *Pan troglodytes*, is able to perform simple analogies with geometric shapes. In the most impressive demonstration of this ability, Sarah is presented with a marker board. In the centre of this board is a symbol which she has been trained to recognise as meaning 'the same as'. She is also given some pictures of geometric shapes. Her task is to construct a shape-based analogy. For example, two circles can be considered analogous to two triangles because they shared the relation of 'sameness'. Sarah is able to construct analogies such as this above chance level.

How is such a feat achieved? How does a chimpanzee recognise the equivalence between sets of shapes? How did a Mesopotamian poet, writing 4000 years ago, come to equate the mourning of a king with the attentiveness of an eagle? How does a pre-linguistic infant recognise the structural similarity underlying two physical problems? An entire section of this volume is devoted to computational models of analogy. The approaches adopted vary from agent-based, to connectionist and hybrid models. However, the models are connected by a desire to locate analogical reasoning within the general context of human cognition. Forbus (chapter 2) applies models of analogy to our ability to reason about physics problems. Kokinov and Petrov's model integrates reasoning by analogy with memory (chapter 3).

By situating analogy within general cognition, the volume is able to move between abstract and applied domains. Bassok (chapter 12), for example, discusses the role of analogy in teaching and learning mathematical word problems.

In their desire to locate analogy at the heart of cognition, some of the authors in this volume define analogy very broadly. In the epilogue, analogy appears to collapse into categorisation. Analogy is, according to Hofstader, 'everything…or almost'. Even if this conclusion goes too far for some readers, the book is an impressive overview of the importance of analogy in cognition.

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