European Association for Research
on Learning and Instruction

Earli

4th European Symposium

Conceptual Change: Philosophical, Historical, Psychological, and Educational Approaches

ABSTRACTS

May 19-23, 2004
Delphi, Greece

European Association for Research
on Learning and Instruction

4th European Symposium
Conceptual Change: Philosophical, Historical, Psychological, and Educational Approaches

May 19-23, 2004
Delphi, Greece

ABSTRACTS

Edited by:
Stella Vosniadou, Christina Stathopoulou,
Xenia Vamvakoussi & Nektarios Mamalougos

Sponsors:
Olympic Airways, Commercial Bank of Greece, Greek Centre of Educational Research, Greek Ministry of Culture, Local Union of Municipalities and Communities in Fokis Prefecture, Gutenberg Publications

4th European Symposium on Conceptual Change
Philosophical, Historical, Psychological and Educational Approaches
Delphi, Greece. May 19-23, 2004

Web Site: http://cs.phs.uoa.gr/delphi2004
E-mail: delphi2004@phs.uoa.gr

Book of Abstracts

© 2004 Stella Vosniadou

Laboratory of Basic and Applied Cognitive Science and Educational Technology
Department of Philosophy and History of Science,
National and Kapodistrian University of Athens, Greece
University Campus, Ano Ilissia, 15771, Athens, GREECE
Tel. Voice: +30 210 727 5506; Fax: +30 210 727 5504

All rights reserved. Permission is granted only for the photocopying of isolated articles for non-profit classroom and library reserve use by instructors and educational institutions. This consent does not extent to other kinds of copying, such as copying for general distribution, for advertising or for promotional purposes, for creating new collective works, or for resale.

Publication: The book of abstracts is published by Gutenberg Press.

Front Cover: The Charioteer (Heniochos). The bronze statue was found at Delphi and originally belonged to a larger group, which represented a chariot with four horses. Its height is 1.8m and is made up from six separate cast parts. It was dedicated to Apollo by Polyzalos, tyrant of Gela, in 478 BC, after he won the chariot-race at the Pythian Games (Archaeological Museum Delphi).

Back Cover: Remains of the Dome, ancient Rotunda Temple, dedicated to Athena, Goddess, of Wisdom (located in Delphi, Archaeological Site).

Contents

Preface & acknowledgements

On behalf of the International and Local Program Committees I would like to welcome you to the 4th European Symposium on Conceptual Change: Philosophical, Historical, Psychological and Educational Approaches, in Delphi, Greece, May 19-23, 2004. This meeting was organized and supported by the Cognitive Science Laboratory and the Cognitive Science Division of the Department of Philosophy and History of Science, National and Kapodistrian University of Athens. It became possible also through the support of the Greek Ministry of Culture, Olympic Airways, Commercial Bank of Greece, Greek Centre of Educational Research, Local Union of Municipalities and Communities in Fokis Prefecture, and Gutenberg Publications.

This volume brings together the abstracts of the keynote lectures, the invited symposia, the papers and the posters of the symposium. They include contributions from leading researchers investigating conceptual change from philosophical, historical, psychological, and educational perspectives. Special emphasis has been given to issues on conceptual change in physics and mathematics as well as the influence of epistemological beliefs and motivational factors on conceptual change.

The organization of this meeting would not have been possible without the expert help of many people. To the members of the local and scientific committees to the organizers of invited symposia, to the many members of the SIG and particularly its coordinators Kaarina Merenluoto and Gunilla Petersson, I would like to express my sincere thanks. I would like to especially acknowledge the help of my colleagues Ola Halldén, Erno Lehtinen, Margarita Limon, Lucia Mason, Aristides Baltas and Bill Brewer. Warm thanks also go to Giorgos Dardanos and Christos Stavropoulos from Gutenberg Publications and to a special crew of students from the University of Athens: Irini Skopeliti, Antonis Koukoutsakis, Athanassios Mol, Katerina Ligovanli, Maria Koulianou, Natassa Kyriakopoulou, Kalliopi Ikospentaki, and Vassiliki Siereki.

Scientific Programme and the book of abstracts owe their existence to the expertise and many hours of work of Xenia Vamvakoussi, Christina Stathopoulou, and Nektarios Mamalougos; my deepest thanks to every one of them.

Stella Vosniadou

Chair of the
4th European Symposium
on Conceptual Change

Commitees of the Conference

Chair of the Conference

Stella Vosniadou	Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece

International Scientific Committee

Aristides Baltas	National and Technical University of Athens, Greece
Ola Halldén	Stockholm University, Sweden
Erno Lehtinen	University of Turku, Finland
Margarita Limón	Universidad Autónoma de Madrid, Spain
Lucia Mason	University of Padova, Italy
Marianne Wiser	Clark University, USA

SIG Coordinators

Kaarina Merenluoto	University of Turku, Finland
Gunilla Petersson	Karolinska Institutet Stockholm, Sweden

Local Organising Committee (University of Athens)

Christina Stathopoulou, Xenia Vamvakoussi	Scientific Programme, Book of abstracts
Nektarios Mamalougos	Web Site, Book of abstracts
Antonis Koukoutsakis	Web updates, Communication
Irini Skopeliti, Erifylli Tsirempolou, Natassa Kyriakopoulou Rania Gikopoulou	Secretariat, Hotels
Athanassios Mol, Katerina Ligovanli	Fund Raising and Catering
Kalliopi Ikospentaki, Maria Koulianou, Vassiliki Siereki	Cultural Activities, Transportation

Wednesday, May 19th

14.30 - 17.00: Keynote Addresses & Panel Discussion

Chair: Ola Halldén, Stockholm University, Sweden

Keynote Addresses

What's Left of Kuhn's Scientific Change: Some Philosophical Remarks

Peter Machamer, University of Pittsburg, USA

Thomas Kuhn's *The Structure of Scientific Revolutions* was published in 1962 (Kuhn 1962). Since it's publication it has sold about 20 million copies and been translated into 18 languages (These figures come from Michael Matthews in a lecture he gave at IHPST in Denver, Nov. 9, 2001). This may well make it the best selling book on history and philosophy of science ever written. Yet most philosophers hated the book, much to Kuhn's dismay, and social scientists loved it, also to his great dismay.

So we well might ask, 42 years later, what's defensible, philosophically, in Kuhn's major theses? Specifically, what about the concepts of normal science, puzzle solving, paradigm shift, theory-ladeness, incommensurability, and the role of values in science are worth saving? And how have they been, or ought they to be, elaborated from Kuhn's terse original?

This lecture will attempt to briefly review these theses and sketch what is right in them and how they need to be modified. The modifications are to make them more philosophically coherent. The uses of the Kuhnian concepts for psychological and educational theory and practices in science education will be discussed.

The Conceptual Change Approach in Psychology and Education: Kuhn's Influence and State of Art

Stella Vosniadou, University of Athens, Greece

Thomas Kuhn’s ideas influenced psychological and educational research in many direct and indirect ways. In the present lecture we will focus on the two most well known research programs that attempted to apply some of Kuhn’s ideas in *The Structure of Scientific Revolutions* to psychology and education. One is the “theory-theory” view in cognitive-developmental research, i.e., the view that children are like scientists, forming theories which they evaluate and revise in the process of

cognitive development. The other is the “conceptual change” approach in science education, an approach which started with an influential paper by Posner, Strike, Hewson, & Gertzog (1982). According to this view, students form misconceptions or alternative frameworks in science which need to be replaced by the currently accepted scientific theories in the process of learning science.

We will attempt to critically review these approaches and evaluate them on the basis of current educational and psychological findings. At the end we will present our views on how to bridge these two research traditions, and on what is worth saving from Kuhn’s original ideas for a theory of learning and instruction.

References

Kuhn, T.S., (1962). *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago

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

Panel Discussion

Aristides Baltas, National Technical University of Athens, Greece
William F. Brewer, University of Illinois at Urbana-Champaign, USA
Noel Entwistle, University of Edinburgh, UK
Vassiliki Kindi, Technical University of Athens, Greece
Marianne Wiser, Clark University, USA

17.30 - 19.30: Paper Sessions

A. Conceptual Change Issues Related to Evidence and Model-Based Reasoning

Chair: Dimitrios Psyllos, Aristotle University of Thessaloniki, Greece

Discussant: John Clement, University of Massachusetts, USA

Conceptual Change and the Evidence-Explanation Continuum in Science

Lucy Avraamidou*, King's College, London, UK, and Richard Duschl, Rutgers University, USA

Introduction

The *National Standards in Science Education* and the addendum to the *Standards* on Teaching Science as Inquiry (NRC, 2000), along with the American Association for the Advancement of Science Project 2061 edited book *Teaching in the Inquiry-Based Science Classroom* (Minstrell & Van Zee, 2000), clearly suggest dissatisfaction with school science programs. Empirical evidence of this dissatisfaction can be found in the recent Project 2061 review of US middle grade science textbooks (AAAS, 1999). The position we develop in this proposal is that an important missing dynamic is the inclusion of inquiry conversations that examine the delicate dialectic between evidence and explanation or observation and theory.

The way forward is to consider frameworks that describe and analyze conversations of inquiry. Contemporary perspectives from: a) the history and philosophy of science (e.g., Ackerman, 1985; Giere, 1988; Hull, 1988; Shapin, 1994); b) the nature of learning and reasoning in science (Carey, 1985; Chinn & Brewer, 1993; Metz, 1995; Schauble et al., 1997; Klahr and Simmon, in press); and c) the design of science education programs (Gitomer & Duschl, 1995, 1998; Lehrer & Schauble, in press; Izquierdo et al., in review; Polman, 2000; Krajcik, Czenrniak & Berger, 1998) have begun to shift the perspective away from final form science to a perspective of 'science-in-the-making'.

We present in this paper a model-based view of science and science education that serves to address the all-important dialectic between observation and theory that focuses on the transformations of data and through which conceptual change occurs.

Evidence-Explanation Approach and Conceptual Change Theory

Built upon Giere's views on model-based science this theoretical paper proposes a contemporary approach to science education: the *Evidence-Explanation* approach.

This approach has its roots in conceptual change theory and emphasizes the epistemic conversations about data transformation in science; e.g., raw data to selected data/evidence to modelled data to explanations. The original conceptual change theory describes the substantive dimensions of the process by which people's central, organizing concepts change from one set of concepts to another set, incompatible with the first (Posner, Strike, Hewson, & Gertzog, 1982). After years of research, a revised theory (Strike & Posner, 1992) was proposed that incorporates the important social and motivational dynamics involved in the growth of scientific knowledge.

The ways in which the evidence-explanation continuum has entered into science education are associated with the conceptual change theory, which 'was based initially on theory-change models in scientific fields and continues to benefit from epistemological analogies between scientists and science learners' (Kelly & Duschl, 2002, p. 17). According to Kelly and Duschl (2002), *Drawing from descriptions of theory change in science [e.g., Kuhn, 1996; Lakatos, 1970; Toulmin, 1972], educators sought characterize students' conceptual change by taking into account the conditions that may lead to conceptual change and the intellectual ecology within which reasoning about ideas and evidence takes place [Strike & Posner, 1992] (p. 17).*

As Posner, Strike, et al. (1982) described, four conditions are common to most cases of accommodation: (a) there must be dissatisfaction with existing conceptions; (b) a new conceptions must be intelligible; (c) a new conception must appear initially plausible; and (d) a new concept should suggest the possibility of a fruitful research program (p. 214). Brown and Palincsar (1989) stated that "conceptual change is more likely to result when the purpose of procedures is emphasized rather than blind drill and practice, even when that drill and practice is devoted to appropriate procedures" (p. 393). Thus, we argue, in this paper it is important to emphasize the process and procedures of data transformation in the evidence-explanation continuum.

Evidence-Explanation Approach

In this paper we argue that the *Evidence-Explanation* (EE) approach can be established based on the cognitive and the epistemological beliefs about science learning. We maintain that knowledge growth and development and beliefs derived from cognitive psychology and philosophy of science serve a fundamental role to this approach. What makes the Evidence-Explanation approach different from the traditional approaches to science education is the emphasis on the *epistemological conversations* that lead to conceptual change. These conservations can best be unfolded through the process of argumentation, which we argue is central to the evidence-explanation approach.

The appeal to adopting the EE continuum as a framework for guiding the design of science education curriculum, instruction and assessment models is that it seeks to work out the details of the process. The EE continuum recognizes how cognitive structures and processes guide judgements about data texts. It does so by formatting into the instructional sequence select junctures of reasoning, what we call, *data texts transformations*. At each of these junctures or transformations, instruction pauses to allow students to make and report judgements. Then students are encouraged to engage in rhetoric/argument, representation/communication and modeling/theorizing practices. The critical transformations or judgements in the EE continuum include:

- Selecting data to become evidence
- Using evidence patterns of evidence and models
- Employing the models and patterns to propose explanations

Another important judgement is, of course, deciding about the selection of data itself. These decisions and judgements are critical entities, we argue, for explicitly teaching students about the nature of science (Duschl et al., 1999). How raw data are selected and analyzed to be evidence, how evidence is selected and analyzed to generate scientific explanations are important 'transitional' steps in doing science. Each transition involves data texts and making judgements about 'what counts'.

Concluding remarks

The significance of developing reasoning skills associated with the evaluation of evidence and the construction of evidence-based explanations has not received enough attention in the field of science education. Chinn and Malhotra (2002) argued that "the ability to reason well about complex models of data is essential not only for scientists but for nonscientists as well" (p. 213). Through an examination of the data-texts and their role in the evidence-explanation approach to science we attempt to make the argument about placing emphasis on the epistemics connected to processes of conceptual change, which in turn will inform both the design and assessment of learning environments.

Multimodal Conceptual Change

Jouni Viiri* and Heikki Saari, University of Joensuu, Finland

A case study involving the conceptual development of students from a multimodal perspective is described. The study finds that a conceptual revision occurs at different speeds in different modes: in talk, in gestures, in the use of equations etc.

Introduction

Research has shown that in conceptual change "knowledge acquisition is greatly facilitated by interactions with peers and particular with a teacher … " (Vosniadou 2001) Knowledge construction interactions frequently occur via language, but researchers have emphasised the importance of other communicative recourses (e.g. Kress et al. 2001). These other modes of interaction may involve gestures, movements, images etc.

This has implications for research into conceptual change, since we would need to collect data concerned with students' gestures, drawings etc. in order to then receive data concerning multimodal conceptual change.

Aims and research questions

The aim of this paper is to examine the conceptual development of students from a multimodal perspective. The paper describes some of the results from a case study designed to track the conceptual development of students in response to a kinematics teaching unit. The results of the role played by teacher talk have already been described in Viiri et al. (2003), and further results will be published elsewhere.

The present article explores the following questions

- How does students' talk develop?
- How have drawings and gestures been used?
- How do the graphs that students draw develop during a problem-solving process?

Research methods

The students who participated in the discussions were 16-17 years of age. From the class four students were selected whose problem-solving was then studied in greater detail. For the process of data-gathering we used small-group discussion. Interviews were not used as we assume that peer discussions may provide a rich context for negotiating shared meanings. Because the discussions were meant to resemble the students' natural peer discussions as closely as possible, interventions by the researcher were kept to a minimum.

The data made up of student talk was collected by means of video-recording, and to record the student's drawings we used an electronic whiteboard. With this equipment we were able to record the whole process of graphing, from the students' initial sketching to the final graph.

Results

We found that gestures reveal conceptual development. Some students cannot describe the solution of the problem in technical terms but they can demonstrate it through gestures. Understanding develops during the discussion from gestures to physics.

Figure 1: The use of gestures and simple language. The student second from the right: *"First there is a curve … then a line, and then a curve*".

The students' use of language developed. At the start of the course, students used everyday language. There was a phase-shift between the teacher's use of language and the students' use of the same concepts. The students did not use the concepts introduced in a lesson in the course of solving the subsequent problem, but they did do so, for example, after a week. At the end of the course the students were able to use the physics terms appropriately.

Subsequent to the development of the use of concepts, the use of equations also developed. The students were able, for example, to use the equation *F=ma* in drawing the force-graph on the basis of the known acceleration-graph.

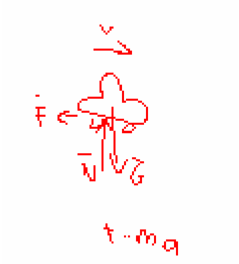


Figure 2: Example of technical drawing

Clear development in their use of technical drawings in argumentation was found. During the course the students started to sketch drawings on the whiteboard at the same time as discussing the problem. In their talk the students were not always able to use the specific terms, but they were able to draw an acceptable picture.

Drawings also helped the students in their reasoning. For example, in one problem they had difficulties in understanding that acceleration may be zero. Figure 3a shows the students' initial acceleration graph. Using a broken line they represented the acceleration going from positive to negative. After adding some tangents on the velocity diagram (Fig. 3b) they were able to state: "So here it does it". By this they meant that they understood that for a moment the slope is at zero. They were then able to draw the final acceleration diagram (Fig. 3c)

Figure 3: Development of the graphs as revealed by the electronic whiteboard

Discussion

We were able to collect useful data about the development of students' drawings by means of the electronic whiteboard. This particular data-gathering equipment was useful since we could load the drawings as electronic material in the computer for analysis and reporting.

We found that gestures were an integral part of students' descriptions of graphs, and that students' language use might have been interpreted differently without the use of videotape and whiteboard data. This observation is in line with those of Moschkovich (1996).

Peer discussion was also a very effective method of gathering data. We also found that students play different roles within their group. Horizontal scaffolding (Hatano et al. 1991) occurred whenever one student scaffolded the others.

Duit (2003) has pointed out that conceptual change is a process of slow revision. Our present study has shown that this slow revision occurs in different modes: in talk, in gestures, in the use of equations etc. at different speeds. In sum, there is multimodal conceptual change.

References

Duit R. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *IJSE* 25 (6), 671–688.

Hatano, G. & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. In L.S. Resnick, J.M. et al. (eds) *Perspectives on socially shared cognition*. American Psychological Association: Washington.

Kress, G., et al. (2001). Multimodal teaching and learning. Continum. London.

Moschkovich, J. N. (1996). Moving up and getting steeper. *The journal of the learning sciences*. 5(3), 239-277.

Vosniadou, S., et al. (2001), Designing learning environments to promote conceptual change in science. *Learning and Instruction* 11, 381–419

Viiri, J., et al. (2003), *Describing the rhythm of science teacher talk*. ESERA 2003 abstracts, 70

It Is the Mind's Eye!: Conceptual Change and the Physics of Seeing & The Epistemology of Perception

James Butler, The University of Queensland, Australia

Context of Paper in Conference

This paper fits perfectly within the Theme of the Conference. In particular, it deals with: relationships between philosophical and educational approaches to conceptual change, specifically the epistemology of perception where the common sense view is so erroneous and Realist that it offers strong resistance to conceptual change processes; conceptual change in Physics, specifically the topic of Light and Vision where the common sense view has been extensively researched but where conceptual change is so very difficult; and motivational issues and conceptual change, managing motivational issues will be specifically addressed in the paper. It also deals differently I hope with issues that will be discussed in the Invited Symposia: changes in Epistemological beliefs, where Realism and Relativism are addressed, but Idealism is, I believe, more important, unless the Symposium presenters subsume Constructivism under Idealism; and Realism and the problem of conceptual change.

Aims

This paper aims to achieve the following:

- To take two contexts, vision and perception, where each uses predominately the eye, and to review the research results about the common sense view about these two very dissimilar processes.
- To review the research literature about more powerful and useful understandings about these two ubiquitous processes
- To take conceptual change as only a precursor to behavioural change, so that changed understandings of vision and perception lead to better ways of behaving
- To illustrate, with data from a course for university academics wishing to become better teachers, the complexity of the conceptual change process when academics move from the common sense view of teaching to the more powerful, more useful, research-based models available at the present time.
- To report on the process of conceptual change, to present results about how it feels to be a person involved in a journey of profound change
- To present the perception curve for conceptual change
- To report the three requirements that our research has shown help people travel the conceptual change journey

Research Design

This paper uses qualitative research methods: document analysis, literature reviews interviews and field notes. The perceptual research models used are derived from the work of Chris Argyris.

Outcomes

The research reported here produces the following outcomes: the paper:

- distinguishes between the physics of seeing and the epistemology of perception, where the former is very limited in its application, whereas the latter is everywhere and is profound in its applications, and is present in what we learn about the former
- shows how the common errors in both are asymmetrical: seeing as active, perception as passive and Realist
- proposes better models: seeing as passive, perception as active and Idealist, and shows how to live within and operate successfully with these
- illustrates perception/conception change in university academics learning to teach; shows how profoundly diverse these perceptions can be, and how individualistic is the journey that people have to make if they are to change their behaviours; the perceptual 'pit' that the academics go through has the following characteristics: The pit of learning, is good educational design, not bad design – it should be designed for, not avoided; The 'pit of learning to behave differently' is an essential human process of change; The depth and the width of the pit is different for different academics

Some academics may not be ready to enter the pit: they need to be respected

Academics enter the pit for diverse reasons and provoked by different stimuli – these reasons and stimuli cannot be predicted or provided with certainty

Bad educational design leaves academics in the pit for the duration of the course

The learning goal available to an academic on the other sides of the pit, cannot be 'seen' or appreciated or understood from the start of the pit, that is the nature of adult transformational learning

- demonstrates how to manage the belief/conceptual change involved in moving to the better models: illustrates the perception curve for people traveling the journey of change, shows how the curve differs for different individuals, and how diverse a group can become when they go through conceptual change
- concludes with strategies, derived from our research, to promote conceptual change: individual courage, strong leadership and collegiality that is both supportive and challenging

Theoretical Significance

This paper's theoretical significance is that it brings together two processes of the eye, shows how their common sense understandings are not always useful, and offers better models. Moving to the better models in both cases involves conceptual change, which can have a profound effect on behaviours. This paper offers a new theory of the perceptual process itself involved in conceptual change, offers a perceptual curve, and offers concrete processes for successfully completing the journey of conceptual change.

Educational Significance

This paper is of great educational significance because it shows how profound is the change that a student must go through to replace the common sense view of vision with the physicist's view of vision. It points to what teachers can do to help students traverse this journey. And it, for the first time I believe, shows teachers the perceptual curve that all teachers must manage if they are to help students learn in the most profound manner, which is the constructivist model of learning.

Short Reference List

Argyris, C. (1982). *Reasoning, Learning and Action*. San Francisco: Jossey-Bass.

Butler, J., Scott, F. and Edwards, J. (2002). '*Evaluating organisational change: the role of ontology and epistemology*', Tamara: The Journal of Critical Postmodern Organization Science, Vol 2, No 2, pp55-65

Viennot, L. (2001) *Reasoning in Physics: The part of common sense*. Dordrecht: Kluwer Academic Publishers.

Learning Conflict: Abstract Theoretical Physics versus Concrete Student Reality

Aletta Zietsman Thomas*, Western Michigan University, and James Thomas, Focus on Learning, Kalamazoo, MI, USA

Abstract

The nature of physics is defined by abstract theories, by a reductionist view of physical phenomena, and the use of physics words with meanings that conflict with normal, everyday, students' definitions of the same word. Further, teachers look for examples of physics principles in context of everyday life, that in reality, do *not* always describes those situations completely. Then, in an effort to make concepts easier for the student to understand, instructors often tweak, or simplify already reduced physics examples. Finally, add to these obvious complications, the fact that students learn from their experiences, and through direct observation of their everyday life, it follows that the students often see the examples presented by the teacher as contrary to what they have observed. Unfortunately, laws often fit only specific circumstances. Unaware of this fact, but sensing that something is wrong with what is presented, the students often do not know how to argue their interpretation successfully with the teacher. Students often give up and go along or worse yet, the conflict between student and teacher goes unnoticed and the student goes on to loath physics forever.

Teaching physics majors (students who plan a career in physics) is very different from teaching physics to prospective elementary school teachers or other students who need a minor in physics. That is to say that physics learners want to know what makes physics do what it does, therefore, physics majors are open to what is being taught and how physics works. On the other hand, other physics learners, prospective elementary teachers, for example, are studying physics to fulfill a college requirement. These students have no genuine interest in the discipline and witness examples and explanations of ordinary physical phenomena that work contrary to what they have witnessed in life. Students will achieve respectable grades for the class, but upon completion of the class return to their original ideas. Students live in the real world and deal with reality, not in the abstract imaginary world of physics; hence, the conflict of learning physics has begun.

The focus of this paper is to observe the problem of the learning physics from three different, and innovative, perspectives.

Physics is an abstract subject - totally defined by human constructs that try to describe and predict how the physical world operates. "Most situations are brought under a law of physics only by distortion, whereas they can often be described fairly correctly by concepts from more phenomenological laws." (Cartwright, 1999, p 31). Teachers have accepted the laws of physics and alternate in their thinking between the physics world and the world of reality, without hindrance going from one world to the other.

Teachers look to nature for examples to explain physics laws and principles. From the statement above, it follows that such examples are often too obtuse to clearly demonstrate the laws. Moreover, teachers then reduce nature to demonstrate how the laws work.

In contrast to the two statements above, the student's knowledge of the world is constructed as a result of their experiences in life, their perceptions, and concrete things. The students' world is one of reality; therefore, defining and accepting abstract and narrowly defined concepts is difficult, especially when the concepts go against the learners' intuitive knowledge.

The data presented here come from:

- The analysis of examples of physics problems.
- An analysis of teachers' reasoning while explaining one of the above physics examples to a physics novice.
- Analysis of students' reasoning while learning about levers.

From the data analyses several new and interesting hypotheses are emerging:

Teachers are unaware that they have changed the natural phenomena, or that they have given an inappropriate example. Teachers believe that physics laws can explain phenomena in the natural world completely. Yet they ignore the various abstractions and assumptions that are needed to "fit" the example to the laws. They try unsuccessfully to link the example with the student's intuitive knowledge. This linking is ineffective because the information being presented by the teacher goes contrary to intuitive knowledge possessed by the student. Thus, in an effort to make learning easier for the student, the teacher actually adds confusion for the students' conceptual understanding.

Students and teachers actually work in two different worlds. The student is in a world of concrete reality and is always trying to link her intuitive knowledge to what is witnessed. On the other hand, the teacher has accepted the laws of the discipline and can freely operate in the world of physics abstraction or reality.

Students can develop what Cartwright calls a “nomological machine”, an abstract situation in which a law applies. By using the nomological machine in different scenarios, students develop the ability to cross into the real world where the nomological machine does not exist (Zietsman & Thomas, in press; Zietsman & Clement, 1997; Clement, Brown & Zietsman, 1987). By adding approximations and constraints students “abstract” the real world to fit their nomological machine and are able to judge whether the laws of physics apply or not. We will present data from an experiment of students learning about levers using such a “nomological machine” that is anchored in the students’ physical intuitions.

References

Cartwright, N. (1999). *The Dappled World*. Cambridge: Cambridge University Press

Clement, J., Brown, D. and Zietsman, A. (1989). Not all preconceptions are misconceptions: Finding "anchoring conceptions" for grounding instruction on students' intuition. *International Journal of Science Education*, *11*(5), 554-565

Zietsman-Thomas, A. and Thomas, J. (in press). Dappled worlds in the learning of physics. To appear in the *South African Journal for Higher Education*

Zietsman, A. and Clement, J. (1997). The role of extreme case reasoning in instruction for conceptual change. *Journal of the Learning Sciences*, *6*(1), 61-89

Scientific Concepts in Model-Based Analysis: Seeking for a Criterion of Concept Identity in the Case of Galileo Inertia

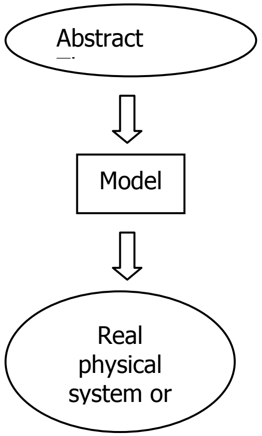
Vassilis Raisis, National Technical University of Athens, Greece

Introduction

In this paper I'm going to presuppose the general thesis that scientific concepts are not determined by definitions but by the *use* in paradigmatic instances. My proposal is that we must understand the concept "use" in terms of two basic abilities that a scientist must possess. Both these abilities are connected in the relative literature to the concept of *model,* or *model based reasoning.*

First Ability or Modeling 1

I shape the first ability based on a common view of many scholars that argued against the standard, propositional view towards science (Cartright, van Fraasen, Giere, Nersessian, etc). According to their view, the conceptual apparatus of a theory doesn't concern natural phenomena per se but entities in idealized cognitive constructions. These constructions (models) in this way mediate between the abstract theory and a physical system, with the duty of representing the latter.

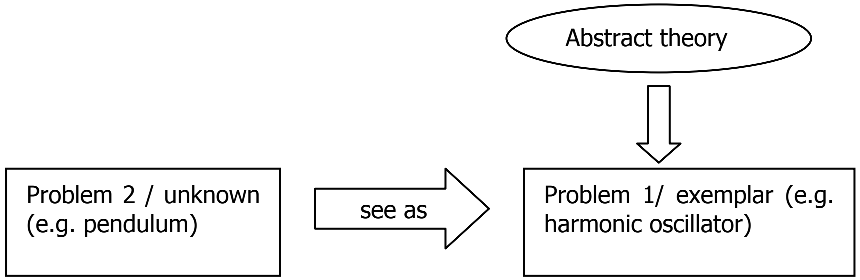


The appropriate use of a concept in this way means that scientists can "move" from abstract entities to real things, for example from "mass points" to real bodies. At the same time, they should be able to isolate from the real, complex situations in the physical world, only the aspects that the model drives him to isolate, for example to *see* a real body *as* mass point. Let me call this ability *modeling 1.*

Second Ability or Modeling 2

I shape the second ability based on another tradition that stressed the analogical character of modeling (Campell, Hesse, Black, Kuhn etc). I'm basing it specifically on Kuhn, according to whom (*Postscript*) concepts and laws in physics mean nothing before they are applied to paradigmatically solved problems (exemplars).

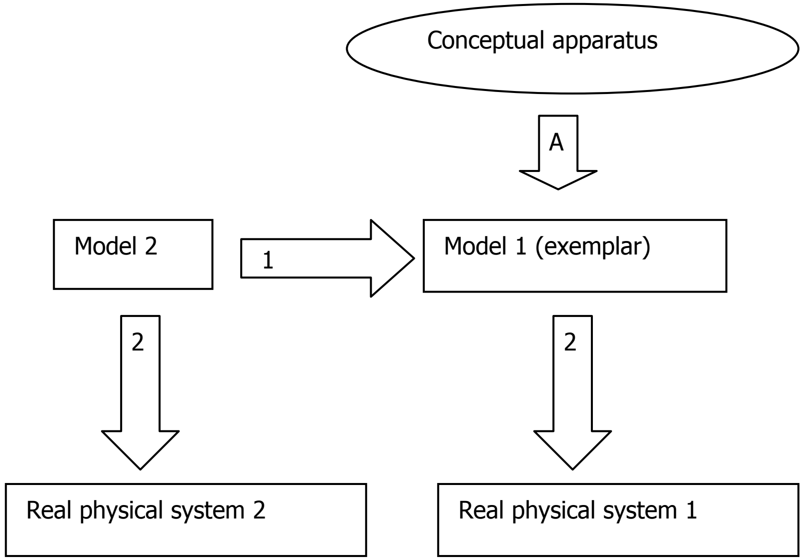
Exemplars, in this way, are situations (real or idealized) such that words/symbols acquire meaning only within them. Therefore concepts are from the beginning embodied in specific situations. In order to apply the conceptual apparatus of the theory to different situations, the scientist has first to «see his problem as a problem he has already encountered» In this way «[s]cientists solve puzzles by modelling them on previous puzzle solutions».



Thus the scientist in order to possess a concept has to possess the ability of "seeing as", of knowing how to reduce one problem to another. This ability is necessary, as new situations are not confronted directly through abstract theory and some *correspondence rules* but they should first be seen as instances of one idealized model. Let me call this ability *modeling 2*.

Combining the Two Abilities; The Question of Galileo's "Inertia"

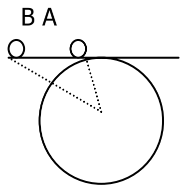
None of these two abilities, I described above, has logical or temporal priority over the other. Actually, the scientist goes from one to another trying to fix a model (model 2) which is a successful representation of a physical system. So, operation A is empty, unless someone can operate with 1 and 2, "seeing as".



In the rest of the paper I see some consequences of the above analysis for a specific historiographic problem concerning Galileo's concept of inertia. The question is, whether Galileo is among the first that shapes the modern inertia principle, namely, that horizontal motion without impediments would be eternal, *or* whether he uses a notion of circular inertia connected with ancient Greek ideas about the central character of circular motion. I'm going to argue that speaking about circular inertia (e.g. in Britannica's lemma for Galileo) presupposes the definitional character of concepts and results in controversial results. My assumption is that the whole question changes radically if one adopts the meaning-as-use considerations.

Galileo's "Inertia" in the Light of Model Based Analysis

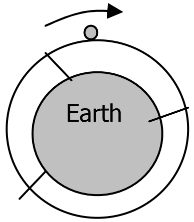
Galileo's exemplary model for the motion is inclined plane. He constructs the relative theoretical model and he knows how to build real planes in order to test theoretical assumptions. When he comes to examine the motion in a plane with 0o inclination (horizontal), he remarks that the motion can't be accelerated nor decelerated; for this reason it should be eternal. Up to this point it seems that Galileo has the modern concept of inertia. But when he examines more carefully the above consideration he finds that it is not correct.



Indeed, he notes that as the body moves "from its midpoint towards its extremities, this [line] departs even farther from the center [of the earth], and hence it is always rising" (Discorsi, 274). Therefore the body must be decelerated as it moves towards B.

So, if we want a really eternal motion, the body should go on a corridor around the earth as in the diagram below.

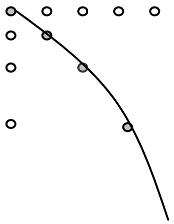
Galileo takes for granted the tendency of the bodies to accelerate towards the center of the earth and as he doesn't have any satisfying explanation he refuses to make any explanatory hypothesis about it. With this assumption he is completely right in supposing that in his model –a frictionless plane- the eternal motion would be around the earth. Paradoxically, Galileo seems to defend a "circular" version of inertia but he is totally "modern" to do so.



Having now the initial concept, as it is introduced in Galileo's exemplar, let me now proceed to the two ways of modeling that I described above.

First, Galileo assumes that for a small part of the cycle we can ignore the curvature and consequently the tendency of the body to move towards the center of the earth. In this way, he can *see* the theoretical model of horizontal perpetual motion *as* limiting case of the model of circular perpetual motion. (modeling 2)

Second, Galileo's "inertia" concept is not just an abstract principle, as he uses his horizontal version of inertia in real problems, namely in projectiles.



Examining the projectiles, Galileo assumes that towards the horizontal axis the body moves uniformally. In this problem he assumes that he can really ignore not only the curvature of earth but the friction of the air as well. His theoretical results concern real projectile motion and is verified by them. So, he knows how to use this *idealized concept,* in real situations. (Modeling 1)

With these two criteria, Galileo seem to have the same concept of inertia that we have today. I think the whole problem emerges when we browse through Galileo's text trying to find a definition, instead of trying to find how Galileo uses the concept of motion without impediment.

Closing Remarks

I close with two remarks. The first regards the difference between science and the everyday formation of concepts. Non-scientific concepts take their meaning in use as well. But I think there is a difference. In science, the modeling 1 and 2, which I described above, is explicit, rigorous and always under discussion via logical and empirical arguments. On the contrary, the use of concepts in new areas of everyday life is tacit and is often debatable as social and ideological conflicts blur the whole issue.

The second remark concerns the pedagogical consequences of my proposal. A common complaint of science's teachers is that students memorize definitions and laws without a real understanding. I believe that the "real understanding" concerns the two modeling abilities I described above.

B. Developmental, Connectionist and Dynamical Systems Approaches to Learning

Chair: Dimitris Stamovlasis, Education Research Centre, Greece

Discussant: Athanassios Raftopoulos, University of Cyprus, Cyprus

Capturing and Modeling the Developing Mind

Andreas Demetriou, University of Cyprus, Cyprus

This presentation presents a longitudinal study designed to contribute to the integration of the information processing, the differential, and the developmental modelling of the mind into an integrated theory. This investigates the relations between processing efficiency, working memory and problem solving from the age of 8 to 16 years. This study involved 113 participants, about equally drawn among 8-, 10-, 12-, and 14-year olds at the first testing: these participants were tested for two more times spaced one year apart. Participants were tested individually with a large array of tasks addressed to processing efficiency (i.e., speed of processing and inhibition), working memory (i.e., in terms of Baddeley/s model, phonological storage, visual storage, and the central executive of working memory), and problem solving (i.e., quantitative, spatial, and verbal reasoning).

Confirmatory factor analysis validated the presence of all of the above dimensions and indicated that they are organized in a three-stratum hierarchy. The first stratum included all of the individual dimensions mentioned above. These dimensions were organized, at the second stratum, in three constructs, namely processing efficiency, working memory, and problem solving. Finally, all second-order constructs were strongly related to a third-order general factor. This structure was stable in time.

Structural equation modelling indicated that the various dimensions were interrelated in a cascade fashion so that more fundamental dimensions proved to be part of more complex dimensions. That is, speed of processing was the most important aspect of processing efficiency and it perfectly related to the condition of inhibition, indicating that the more efficient one is in stimulus encoding and identification, the more efficient one is in inhibition. In turn, processing efficiency was strongly related to the condition of executive processes in working memory, which, in turn was related to the condition of the two modality-specific stores (phonological and visual). Finally, problem solving was related to both processing efficiency and working memory, the central executive in particular.

All dimensions appear to change systematically with time. Growth modelling suggested that there are significant individual differences in attainment in each of the three aspects of the mind investigated. Moreover, each of the three aspects of the mind as well as their interrelations changed differently during development. Mixture growth modelling suggested that there are four types of developing

persons, each being defined by a different combination of performance in these aspects of the mind. Some types were more efficient and stable developers than others. These analyses indicated that processing efficiency is a factor closely associated to developmental differences in problem solving whereas working memory is associated to individual differences. Modeling by logistic equations uncovered the rates and form of change in the various dimensions and their reciprocal interactions during development.

These findings are discussed from the point of view of information processing, differential, and developmental models of thinking and an integrative model is proposed.

A Connectionist Model of Conceptual Change

Timo Honkela*, Krista Lagus and Jaakko Särelä, Helsinki University of Technology, Finland, and Kirsti Lonka, Karolinska Institute, Sweden

In this article, we consider the possibility of computational modeling of conceptual change. We focus on the connectionist models that seem to provide more realistic basis for conceptual modeling than the traditional methods based on purely symbolic representations such as semantic networks. However, we also consider the link between symbolic and connectionist levels.

Individuals construct certain beliefs that are based on their everyday experience and, depending on the domain; the knowledge acquisition process requires a revision of some of those beliefs and their replacement with a new explanatory structure. This process may be called conceptual change (see, e.g., Vosniadou 1994). In current cognitive learning theory, three core conceptions may be identified (Lonka et al. 1996). The first concept, constructivity, is the idea that knowledge and cognitive strategies are constructed by the learner, and that learning involves qualitative restructuring and modification of schemata, rather than just the accumulation of new information in memory. The second concept, active epistemology, is closely related to constructivity, but refers specifically to beliefs about the learner's role in the learning process. Mental representation is the third core concept. In cognitive learning theory, performance on problem-solving tasks and students' explanations of such tasks are most often accounted for by the nature of their mental representations and also by their prior knowledge. Moreover, representations are highly situational (Brown et al. 1989) and knowledge is socially shared and constructed (Resnick 1996, Salomon 1993).

Tynjälä et al. (2002) discuss the ontology of concepts. Based on (Thagard 1992) they present that concepts can be seen as "entities" or "non-entities". Concepts as entities could be nonnatural, abstracted, linguistic or mental (either innate or largely learned). Concepts as non-entities could be either fictions or emergent states. Within connectionist models concepts are usually considered as emergent states (cf., e.g., Churchland 1989). Connectionist models are computational models that attempt to capture some structural or functional features of human brain. Within connectionism concepts can be considered as mental patterns rather than entities. Key ideas include that these patterns are learned and there is a connection to the perceptual domains.

Many traditional epistemological theories of concepts have been based on the basic assumption is that the world consists of objects, events and relationships. The language and the conceptual structures and then supposed to reflect this ontological structure. In this framework, learning the meaning of words and expressions has been seen as a means to memorize the mapping from the epistemological domain (to put it simply: words) into the ontological domain (objects, events and relationships). The use of (predicate) logic and the von Neumann computer as the model or metaphor of human learning and memory has strengthened the idea of the memory as a storage of separate compartments which are accessed processed separately and which are used in storing and retrieving information more or less as such. In philosophy and cognitive science, there have been several opposing views (e.g. Niiniluoto 1991) but there have been little means to model or formalize these ideas without connectionist models.

The self-organizing map (Kohonen 1982, 2001) can be considered as a memory model and as a model of constructivist learning. It is dynamic, associative and consists of elements that can also be called adaptive prototypes. Inputs are not stored as such but comparison is made between the input and the collection of prototypes. The closest prototype of the input is adapted towards the input. The same operation is also conducted for the neighboring prototypes, which gives rise to the topographical order on the map. Thus, the adaptation process in the self-organizing map algorithm is based on the principle that what already exists in the system also influences the learning result.

Gärdenfors (2000) offers a theory of conceptual spaces as a bridge between the symbolic (such as semantic nets) and connectionist approaches (such as self-organizing maps). In his theory, conceptual space is built up from geometrical structures based on a number of quality dimensions. As suggested by Gärdenfors (2000), one can consider the output space of the self-organizing map as a computational model of a domain: it is an ordered representation that is made up by integral "dimensions". As pointed out by Kohonen (1990), topological closeness and connectivity of representations alleviates the "property inheritance" problem found in semantics and artificial intelligence. He also gives several examples of sensory-level maps: acoustic (tonotopic) maps, phonemes of speech, colors, all of which have been produced by analyzing particular natural signals.

In our presentation, we will consider which aspects of the conceptual change can be adequately modeled using self-organizing maps. We will also present some theoretical and practical implications. Practical implications include development of tools for collaborative learning environments such as presented in (Honkela et al. 2000). Our presentation also provides some specific hypotheses for empirical and experimental research.

References

Brown, A.L., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18, pp. 32-42.

Churchland, P.M. Learning and Conceptual Change. Chapter 11 in A Neurocomputational Prespective: The Nature of Mind and the Structure of Science. Cambridge, Mass.: MIT Press.

Gärdenfors, P. (2000). Conceptual spaces: The geometry of thought. MIT Press.

Honkela, T. (1997). Learning to understand: general aspects of using self-organizing maps in natural language processing. In D. Dubois (ed.), *Computing Anticipatory Systems, Woodbury*, New York: American Institute of Physics, pp. 563-576.

Honkela, T., Leinonen, T., Lonka, K. & Raike, A. (2000). Self-Organizing Maps and Constructive Learning. *Proceedings of ICEUT'2000, International Conference on Educational Uses of Communication and Information Technologies*, Beijing, China, August 21-25, pp. 339-343.

Kohonen, T. (1990). *Internal representations and associative memory*. Parallel Processing in Neural Systems and Computers, pp. 177-182.

Kohonen, T. (2001). *Self-Organizing Maps*, 3rd Ed. Berlin & Heidelberg: Springer.

Leiser, D. (1996). Constructivism, epistemology and information processing. *Anuario De Psicologia*, 69, pp. 93-113.

Lonka, K., Joram, E. & Bryson, M. (1996) Conceptions of learning and knowledge - does training make a difference? *Contemporary Educational Psychology*, 21, pp. 240-260.

Niiniluoto, I. (1991). Realism, relativism, and constructivism. *Synthese*, 89, pp. 135-162.

S. Lehti & K. Merenluoto (eds.), Proceedings of the 3rd European Symposium on Conceptual Change, pp. 242-250.

Resnick, L.B. (1996). Situated learning. In E. De Corte & F.E. Weinert (eds.), International encyclopedia of developmental and instructional psychology, Kidlington, Oxford: Pergamon Press, pp. 341-346.

Salomon, G. (ed.) (1993). Distributed cognitions: Psychological and educational considerations. New York: Cambridge University Press.

Tynjälä, P., Merenluoto, K. & Murtonen, M. (2002). What has been meant by 'concept' and 'change' in conceptual change studies? A framework for a meta-analytical study. in S. Lehti & K. Merenluoto (eds.), *Proceedings of the 3rd European Symposium on Conceptual Change*, pp. 28-45.

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

Testing Dynamical Hypothesis in the 'Ontological Space' of Basic Scientific Concepts

Dimitris Stamovlasis*, Education Research Centre, and Vassilis Tselfes, University of Athens, Greece

Introduction

The latest psychological theories of conceptual representation in declarative memory have characterized semantic memory as a hierarchical associative network (Newell, 1994). In science education research the metaphor of associate networks of meaning has been used to understand students' 'ontological space' of fundamental scientific concepts (Ogborn & Koulaidis, 1988; Mariani & Ogborn, 1991). It has been shown by multidimensional scaling techniques that the 'ontological space' where supposedly the students' reasoning operates has a number of dimensions that bear a close relationship to the fundamental categories-features attributed to scientific concepts (Mariani & Ogborn, 1991). This research work was based on Piagetian view of the genesis of fundamental ontological categories.

Each concept in semantic memory is associated with a number of features or attributes (categories). In order to determined or defined each concept, that is to access the semantic associative network, one can implement a questionnaire and follow a decision-making procedure of "Yes" or "No" responds. From the information-processing point of view, the human processor is compressing or abstracting the environmental stimuli, thereby causing the external word collapse onto a set of 'categories'. The 'meaning' can emerge after a number of judicious dichotomies (Yes/No) or a cascade of broken symmetries (Nicolis, 1991). This process has been proposed as dynamical one performing at the 'edge of chaos', by giving a theoretical model but without providing any empirical evidence.

In the present study we tested a dynamical hypothesis in a sequence of judicious dichotomies, in a process of accessing students' associative network of conceptual representation. The hypothesis states, that this process of accessing students' 'ontological space' of fundamental science concepts has dynamical characteristics. Results of these tests are provided and the implications of the findings are discussed.

Methodology, Data Analysis and Results

We developed a written questionnaire (Q1) in which subjects were asked basic ontological questions about ten scientific concepts. The questionnaire was based on Mariani & Ogborn's work (1991). The selected concepts were: Time, space, matter, energy, movement, force, light, sound, heat and pressure.

Each questionnaire took the form of a grid, with ten scientific concepts across the top and a list of sixty-six features down the side. Subjects (five education-students) were asked to decide, for each concept, whether or not it possessed each feature. Examples of features-attributes used are of the type:

'You can move thing with it', 'you can touch it', 'you can see it', 'it is like a particle', etc.

The answers were in the form of "Yes" or "No", and they sum up to six hundred sixty. A week later, each subject was asked to complete a second questionnaire (Q2) containing the same questions in a different order. The answers from each questionnaire were converted to an array of symbols. Each created symbolic sequence was then treated as dynamical flow, and it was studied for its nonlinear characteristics. In order to study the dynamic characteristics of the created sequences we employed the random walk methodology (Tselfes, 1994; Stamovlasis & Tsaparlis, 2001).

We introduce a graphical representation of the sequence, which could be termed a concept random walk. We define the function $\Psi(i)$ as follows:

$\Psi(i) = -1$, for decision "No"; $\Psi(i) = +1$, for decision "Yes"; random walk, RW

For each subject then we created two sequences Q1 and Q2, and two random walk, RW1 and RW2 respectively. Consequently, the nonlinear correlation exponent, the Hurst (H) exponent was calculated by rescaled range analysis and surrogate method. If $H \neq 0.5$, then scale-invariant, long-range correlations there exist. The value of H in these symbolic sequences depends: a) on the questionnaire ("input pattern") b) on the subject's answers (output).

If the answers have not been significantly altered by the dynamics of the stimuli (Q2), then RW1 and RW2 must have similar nonlinear characteristic. These characteristics refer to 1/fb dynamics.

Results, Conclusions and Implications

The analysis of the dynamic sequences revealed different nonlinear characteristics. The scale invariant long-range correlations in RW1 and RW2 were statistically different ($p < 0.05$, surrogate method). It is evident that the 1/fb dynamics imposed by the patterns of input stimuli (Questionnaire) affects the intrinsic process of decision-making and alters the output (answers) that reflects the identity of the fundamental- science-concept 'ontological space'. This finding provides empirical evidence that in this process each step has an impact on the future steps or each step at a given moment of time is affected by of the system' s 'history' (in Prigogine's sense).

The findings of this analysis have important theoretical implications. They add to the dynamical system approach to cognition, by testing a dynamical hypothesis at the behavioral level. They support models, which view the concept-networks not as static structures, but as dynamical distributed representations, which are observed as products of coupling between patterns of external stimuli and the intrinsic process of thinking. The evidence of this coupling raises issues of self-organization (Haken, 1988).

Dynamics has already been used in educational research as a metaphor, but never any quantitative evidence has been provided. Current psychological theories of conceptual change are important to educational practices (Vosniadou, 1994; Mason, 2001), and they could profit from the latest advance in neuroscience. Teaching and learning, problem solving or performing any mental task, cannot be described within the linear frame of reductionism; instead it would be fruitful if we reexamine fundamental laws underling brain functioning. Research in science education can learn from the emerging science of complexity (Nicolis & Prigogine, 1989) by fostering nonlinear concepts and tools to model and describe phenomena.

References

Haken, H. (1988) Information and self-organization (a macroscopic approach to complex system). Springer: Berlin.

Mariani, M., C. & Ogborn, J. (1991). Towards an ontology of common-sense reasoning. *International Journal of Science Education*, 13, 1, 69-85.

Mason, L., (2001). Instructional practices for conceptual change in science domain. *Learning and Instruction*, 11, 259-429.

Newell, A. (1994). *Unified Theories of Cognition*. Cambridge. Harvard University Press.

Nicolis, J., S. (1991). *Chaos and Information Processing*. World Scientific: London.

Nicolis, G. & Prigogine, I. (1989). *Exploring complexity*. W. H. Freeman and Company, New York.

Ogborn, J. & Koulaidis, V. (1988). Use of systematic networks in the development of a questionnaire. *International Journal of Science Education*, 12, 1, 51-66.

Stamovlasis, D. & Tsaparlis G. (2001). Application of complexity theory to an information-processing model in science education. *Nonlinear Dynamics, Psychology and Life Sciences*, 5, 267-286.

Tselfes, V., (1994). The identity of the "semantic space": Presupposition for understanding conceptual change. *Contemporary Education*, 78, 73-87, (in Greek).

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

Self-Organization on the Individual and Communal Levels: Learning and Knowledge Building

Shoshana Keiny*, Malka Gorodetsky and Ety Hagai, Ben Gurion University, Israel

The concept of self organization is a conceptual framework that attempts to describe and understand processes of learning and construction of new knowledge. It serves as a mechanism to describe the emergence of unpredictable knowledge from basic understandings of individuals or collaborative learning communities. In this paper it will be used as an explanatory tool as well as an outcome of a collaborative community of learners. It will enable us to zoom-on the process as well as on the emerging knowledge of the individuals and that of the community. The nature of the emerging will be analyzed in the terms of 'learning' and 'knowledge construction' as suggested by Berieiter (2002).

Bereiter (2002) following Popper (1972) addresses knowledge as existing in three worlds. Learning that is directed towards improving personal knowledge dwells mainly in world 2 whereas knowledge building that is directed towards the construction of conceptual artifacts exists in the 3rd world. Learning is a process that is mainly associated with the individual where as for knowledge building a collaborative community is essential. This differentiation between the individual and the community's nature of learning, will enable us to analyze the process and product, on the two levels. The analysis will address the concept of self organization as the predicate of the analysis as well as the mechanism that leads to the new understandings.

The conceptual framework of self organization is associated with the connectionist nature of the mind or with the metaphor 'Mind-as-a-Rhizome' suggested by Duffy & Cunningham (1996), to describe the mind as an open network of roots that have no hierarchy, order or structure, no inside or outside. It is a model of the mind inclusive of distributed social, cultural, historical and institutional contexts that under dialogues, through semiotic mediation, enable the emergence of innovative new understandings.

The community is playing a crucial part in the processes of emergence. It provides the context for enculturation of the individuals to become participants in the specific community and at the same time it provides the setting for extending the horizons of the involved individuals. It is a setting for generating 'true conversation' (Belenkey, (1986) that due to the diversity of the individual participants may lead to the increase in the collective intelligence and creativity.

As stated above this paper attempts to follow the undergoing process within a community of learners on two levels: that of the individual learners and that of the collaborating community. Although the two processes are interrelated, yet they generate and involve different kinds of knowledge

The analysis is carried out in our community of learners, referred as a "discourse group". It consists of six educational researchers, each of them acting as a group facilitator of an educational change project, in different educational settings. The group has been meeting regularly for five years, with the aim of gaining a deeper understanding of the mutual process of learning. Each meeting of this group was recorded, transcribed and then handed over to all participants for further reflection and analysis. This accumulated data base served for our discourse analysis.

As mentioned, the analysis employs the term "self-organization" (SO), introduced into the group discourse by one participant, a biologist,

Referring to SO in ecological terms namely, the need of a dynamic system to regain its ecological equilibrium by generating a higher level equilibrium, she was looking for ways of translating this metaphor to a positive feedback mechanism in her educational setting.

The idea was picked up by the group, and illuminated by other participants from their different perspectives. With further elaborations, SO turned into a conceptual framework, a viable metaphor for interactive human systems that could enhance participants' understanding of the learning processes undergoing in their own group. It was recognized as a concept that can be employed on different levels of analysis, thus by, reciprocally, extending the understanding of the concept SO itself. The analysis will disclose the interwoven interactions between the individual and the group and highlight the process and the products of these discussions.

The Mechanism of Conceptual Change: Can Connectionism and Dynamical Systems Provide an Explanatory Framework? Theoretical Issues Concerning Conceptual Change Research

Katerina Chryssanthopoulou, University of Athens, Greece

This paper approaches *dynamically* functioning *neural network* systems as a *metaphor* that might give an insight in the attempt to explain the mechanisms of *conceptual change* in *humans.*

In an analogy to the brain, an entity made up of *interconnected neurons*, neural networks are made up of interconnected processing elements called units, which respond in parallel to a set of input signals given to each. A neural network consists of four main kinds of parts:

1. *Processing units*, where each unit has a certain activation level at any point in time.

2. *Weighted interconnections* between the various processing units, which determine how the activation of one unit leads to input for another unit.

3. *Activation rules* which act on the set of input signals at a unit to produce a new output signal, or activation.

4. Optionally, *learning rules* that specify how to adjust the weights for a given input/output pair.

Since the 80s the characteristic of *dynamic self-organization* of *automata* has seemed very challenging to describe *physical cognitive systems*: in the case of automata (that is, systems with interactive constituent units) some total *patterns* (or dissipative structures) seem to *emerge* in the "*behavior*" of the system, without having been programmed. It seems safely daring to assume an *analogy* between the emergence of *stable content states* of such artificial learning systems and the settling of new *(symbolic) content* of the *human cognitive system(s)*. An important aspect of such an observation may be that it is not symbols alone that matter in a cognitive system but the complex *activity patterns* that constitute the cognitive network; adopting such a view, we need not even answer to questions like, "how symbols take their meaning", or, "what is the content of the representations of concepts" (Varela, Thompson & Rosch, 1993).

Learning is essential to most neural network architectures – but what is really meant by saying that a processing element learns? Learning implies that a processing unit is capable of *changing* its *input/output behavior* as a result of *changes in the environment*. In a neural network, learning can be *supervised*, in which the network is provided with the correct answer for the output during training, or *unsupervised*, in which no external teacher is present.

The term "*conceptual change*" refers to the change of *content* of the human cognitive system(s). Conceptual change may occur within a certain cognitive *domain* (content change) or *across domains* (content and structure change – in "tree jumps", Thagard (1992)), at various stages of development. As for the temporal parameter of the transformation, it seems that conceptual change occurs *gradually* and does not consist an abrupt modification into another cognitive state (Vosniadou, 1994). New concepts may be viewed *as resulting states* of a learning system when "filled-in" with new content and structured according to the context where they occur; neither concepts themselves nor their properties need exist as permanent representations (Barsalou, 1987).

According to Vosniadou (1994) "some kinds of conceptual change require a simple *addition* of new information to an existing conceptual structure. Others are accomplished only when existing beliefs and presuppositions are *revised*…. *Misconceptions* are interpreted as individuals' attempts to assimilate new information into existing conceptual structures that contain contradictory information" (p.45).

In connectionist terms, this may correspond to the emergence of *new attractors* in a dynamical system and a *repositioning* of the points that realize *representational states* in high dimensional *state spaces* (Horgan & Tienson, 1996) or to the changes in the *connection weights* and network structure (Elman et al, 1996, Schultz et al, 1996). The attractors of the system are actually the *activation states* into which a network may *settle* into after it is provided with an input signal – that is, new information. These attractors form the state-space toward which the system evolves in time when learning. Adaptive or generative neural networks functioning as dynamical systems can modify their structure during learning by adding or deleting notes and changing their learning state. In the connectionist account the states of a cognitive system are depicted by the *sets of activation values* of the constituent units of the system that distributively encode these states.

Change is modeled by means of *transitions* in the state space of a dynamic system. *New information* input into the learning system is transformed as follows: in the beginning, a given input moves the system into an initial state realized by an initial point in the state-space. The system is thus activated and activation spreads so as to cause the units of the system to change their states. This process may take several steps. Any pattern of activity of the system's units corresponds to a point in its activation space thus these changes correspond to a *movement of the initial point in the state-space*. When a network settles this point arrives at an attractor. The *distributed encoding* of any cognitive state in such a network does not involve all units of the system. So, there will be points that may realize more than one cognitive state at the same time. In other words, the same *representational pattern* may be involved in the representation (that is, it may stand as a symbol) of many different concepts, depending on the total activation of the network.

Connectionism, in the framework of Parallel Distributed Processing (*PDP*) in the AI field, has attempted to explain *cognition* as a multi-dimensional space of all possible behaviors of a learning dynamical system under particular *environmental* and *internal pressures* and *constraints* (relative to the content, architecture, growth rate and environment of the system) and cognitive states may be explained as "snapshots" in the evolution of such a process.

In such a framework, connectionism and dynamical systems may provide *a set of tools* to understand the emerging forms of knowledge (when a *learning system* inputs *new* information or *revises* already existing information) as well as the interaction of the various *constraints* that put pressures on the human cognitive system(s) during the process of *conceptual change*.

References

Barsalou, 1987; The instability of graded structure: Implications for the nature of concepts, in Bechtel & Abrahamsen, 1991

Elman J., Bates E., Johnson M., Karmiloff – Smith A., Parisi D. & Plunkett K., 1996, *Rethinking Innateness*, Bradford, MIT Press

Horgan & Tienson, 1996, *Connectionism and the philosophy of psychology*, MIT Press, Cambridge Mass

McClelland, 1989, Parallel distributed processing: implications for cognition and development, in Morris (ed), *Parallel distributed processing: Implications for psychology and neurobiology*, Oxford University Press

Schultz, Schmidt, Buckingham, Mareschal et al, 1995, Modeling cognitive development with a generative connectionist algorithm, in Simon & Halford (eds), *Developing cognitive competence: new approaches to process modeling*, Hillsdale, NJ: Erlbaum

Shannon, B, 1993; The representational and the presentational: an essay on cognition and the study of mind, Harvester Wheatsheaf

Smolensky, 1988; On the proper treatment of connectionism, *Behavioral & Brain Sciences*, 11, 1-74

Thagard, 1992, *Conceptual Revolutions*, Princeton University Press, NJ

Van Gelder & Port, 1995, *Mind as Motion*, MIT Press, Cambridge, Mass

Van Gelder, 1998a, The dynamical hypothesis in cognitive science, *Behavioral and Brain Sciences* 21

Varela, Thompson & Rosch, 1993, *The embodied mind: cognitive science and human nature*, MIT Press, Cambridge, Mass

Vosniadou S., 1994, Capturing and Modeling the Processs of Conceptual Change, *Learning and Instruction*, 4, 45-69

C. Sociocultural Approaches to Conceptual Change

Chair: Kristiina Kumpulainen, University of Oulu, Finland

Discussant: Lucia Mason, University of Padua, Italy

The Sociocultural Trajectories of Children's Conceptual Thinking in a Technology-Enriched Early Years Science Classroom

Kristiina Kumpulainen* and Satu Vasama, University of Oulu, and Marjatta Kangassalo, University of Tampere, Finland

The goal of this study was to investigate the nature of children's explanations emerging in a technology-enriched early years science classroom. Of specific interest were the intertextual elements of children's explanations constructed during a 5-month science unit focusing around natural phenomena. The overall goal of the study was to investigate how the inquiry-based science unit, including its tools and activities, created the children social spaces to engage in the activity of explaining.

In the traditional conceptual change research tradition, explanations are often investigated as monological acts of language and cognition; witnessing the nature of conceptual understanding the individual holds of a particular phenomenon (cf. Bachman & Grossen, 2001). Typical to this strand of research has been to de-contextualize explanations from the social and physical contexts in which they are created. Less attention has been paid to the interactional and sociocultural context of the explanation activity (Saljö, 1999). In following the sociocultural and discursive approach to conceptual thinking and learning, in this study we conceptualize explanations as interactional achievements shaped by the sociocultural context of activity (Kelly & Green, 1998; Lemke, 1990; O'Loughlin, 1992; Wertsch, 1991)

Study

Data sources. This study is situated in a Finnish early years science classroom consisting of 22 children aged between six to seven years old. Of the 22 children, thirteen were girls and nine were boys.

Pedagogical Context. The pedagogical culture of the classroom community investigated in this study followed inquiry-based science learning modes (e.g. Engle & Conant, 2002; O'Loughlin, 1992; Varelas & Pappas, 2003). In the instructional unit of the present study, dealing with the concepts of earth, space and time, the explanation-generation was grounded on student-initiation. Thus, emerging explanations were guided by the children's questions and they could rest on everyday or scientific reasoning facilitating the participation into scientific inquiry from diverse frameworks and interpretations (Kelly & Green, 1998).

Technological tool. Peer-centred learning activities during the science unit utilized a Pictorial Computer-based Simulation program, PICCO designed to support the children's conceptual learning via self-initiated exploration (Kangassalo, 1997). The program concentrates on a natural phenomenon in earth and space level. The chosen natural phenomenon simulates the variations of sunlight and the heat of the sun as experienced on the earth at user chosen time points and seasons. The program also models the selected phenomenon via highlighting the inter-related positions of the Earth and the Sun in space. PICCO multimedia program has been designed in a way that a child may explore the science phenomena from familiar to unfamiliar, from everyday experiences to more distant ones. In the program all necessary elements are represented as pictures and familiar symbols. Presented phenomena are realistic and in a scale corresponding to reality. Nature pictures in the Picco program are from the children's home town Tampere. The program does not presuppose any reading ability.

Modes of inquiry

The data for the study were collected by means of video-recordings covering adult-child interviews and children's self initiated activities and interactions within the social context of the multimedia science learning tool, PICCO. The whole data collection procedures of this study took place over a five-month period.

Dialogic interviews between an adult and a child. All children who participated in the study were interviewed at the beginning and at the end of the science learning unit. The interviews aimed at illuminating children's conceptual models of natural phenomenon in question. The mode of interview was dialogic in nature, enriched with hands on activities, e.g. modelling of clay into the shape of earth and sun

(visualization of the phenomenon) and describing various science phenomena through pictures.

Peer-centred activities. During the science learning unit, the children had the ability to conduct their science investigations with the PICCO multimedia program freely according to their own interests. The explorations around the technological tool were realised in solo activity or in child-selected dyads or small groups. This period lasted for four weeks.

Data analysis

The interviews and peer-centred activities around the social context of the technological tool were videotaped and transcribed in full. The transcribed video data was inserted into a qualitative analysis program, Nvivo. In order to gain an understanding of the thematic context(s) of peer interaction, it has been important to conduct a content analysis first. After several readings of the transcripts, 13 themes were identified in the interaction. Namely these were: *math, writing, technical, role negotiation, personal, birds, flora, day-night, months, seasons, map, animals and space.* Secondly, all science-related utterances expressed by the children were identified and extracted. Thirdly, the identified science-related explanations were investigated several times in order to establish a typology of categories characterizing the intertextual nature of the explanations. The classification and categorization of the intertextual nature of the children's explanation have been influenced by earlier studies investigating students' explanations in science classrooms. Namely, the typology of intertextuality is grounded upon the work of Varelas and Pappas (2003).

Results

The results of this study suggest that inquiry-based early years science instruction which values learners' problematization, authority and accountability and which is enriched with relevant technological resources is able to create rich contexts for explanation construction. In this social context science gets constructed via diverse discursive voices and explanations (Engle & Conant, 2002).

The children's explanations during the science unit were found to draw on textual and material links, hands-on explorations, i.e. activity links, as well as on recounting events. These intertextual linkages functioned as tools for the children (a) to share and validate previous experiences as sources of knowledge, (b) to establish reciprocity with each other in meaning-making, (c) to define themselves as learners of science and as individuals with specific experiences and background (d) to construct, maintain and contest the cultural practices of what it means to do and learn science in the classroom. Taken together, these intertextual links and the functions they served constructed a local culture and genre of doing science in this classroom (Lemke, 1990). In this culture the children appear to learn to understand the value and applicability of their experiences as tools for problem-solving and thinking in science. Here, the children are likely to learn to think with their experiences – not only to think of them (Enedy, 2003).

Conclusions

In sum, the results of this study suggest that inquiry-based early years science learning activities enriched by technological resources supports the children's social interaction and explanation construction upon scientific phenomena. The intertextual richness of the children's explanations particularly in terms of making connections to their experiences highlights the significance of this social context for explanation elaboration. Moreover, this finding indicates that inquiry-based science learning activities are powerful contexts to examine children's explanations and the sociocultural contexts in which they are embedded.

The instructional context investigated in this study was not specifically designed to support the children's learning of the epistemic game of explaining during scientific inquiry. Rather, the context provided the children with opportunities to express and elaborate their explanations, experiences and interpretations whilst making sense of scientific phenomena. Here, the instructional context was based upon the child's own initiation and social activity whilst the children explored the concepts around earth, space and time. In the future, it might be interesting to examine in more detail whether one could situate specific instructional support into children's activities in order to provide them with better opportunities to move flexibly between various discourses and, perhaps even more importantly, to gain an understanding of the meaning of different intertextual links for scientific inquiry.

References

Bachmann, K., & Grossen, M. (2001, August). *Explanations as interactively achieved learning practices.* A Paper presented at the Annual Conference of the European Association for Research on Learning and Instruction (EARLI), Fribourg, Switzerland.

Enedy, N. (2003). Knowledge construction and collective practice: At the intersection of learning, talk, and social configurations in a computer-mediated mathematics classroom. *Journal of the Learning Sciences, 12*, 361-407.

Engle, R.A., & Contant, F.R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*, 399-483.

Kelly, G. J., & Green, J. (1998). The social nature of knowing: toward a sociocultural perspective on conceptual change and knowledge construction. In B. Guzzetti, & C. Hynd, *Perspectives on conceptual change: multiple ways to understand knowing and learning in complex world* (pp. 145-181). Mahwah, NJ: Erlbaum.

Lemke, J. L. (1990). Talking science: Language, learning, and values. Norwood, NJ: Ablex.

O'Loughlin, M. (1992). Rethinking science education: Beyond Piagetian constructivism – toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching, 29*, 791-820.

Säljö, R. (1999). Concepts, cognition and discourse: from mental structures to discursive tools. In W. Schnotz, S. Vosniadou, & M. Carretero, *New perspectives on conceptual change* (pp. 81-90). Oxford: Elsevier.

Vosniadou, S. (1999). Conceptual change research: state of the art and future directions. In W. Schnotz, S. Vosniadou, & M. Carretero, *New perspectives on conceptual change* (pp. 3-13). Oxford: Elsevier.

Wertsch, J. (1991). Voices of the mind: a sociocultural approach to mediated action. Cambridge, MA: Harvard University Press.

Communicational Dimensions towards Shared Understanding

Evie Trouki, Educational Technology Lab, National and Kapodistrian University of Athens, Greece, University of Athens, Greece

Following the approach that learning is a social process of meaning construction (Vygotsky, 1978), language is viewed not simply as a means for transferring ideas but merely as a tool for exploring ideas (exploratory talk, Barnes, 1992; Mercer, 1995). Computer-based environments built for exploration and meaning construction (Kynigos, 1995) have promoted researchers' interest in language as a social mode of thinking and helped to re-establish the discussion on peer-talk, resulting in the spread of terms such as meaning negotiation, shared understanding and co-construction of knowledge. This terminology reflects the emphasis on communicative processes and indicates the interconnection between cognition and communication. Towards this direction I suggest that discussion on conceptual change may be augmented when is informed by findings concerning communicational dimensions of students' collaboration.

Considering communication as a dynamic process of co-orientation and repair misunderstandings (Schegloff, 1991), the interactants express meanings and work on them by asking or providing clarifications, explanations and modifications. Therefore, talk-in-interaction can be viewed as a field for revising and refining ideas in the process of achieving shared understanding. This study suggests that during this process the interaction with the software can be only one dimension in helping students to achieve conceptual shifts, whereas the intra-group interaction can be a most important aspect concerning opportunities offered for rethinking on ideas.

Thus, one critical question I attempt to answer is what types of group-talk can be expected to encourage working on ideas and gaining mutual understanding. The answer to this question helps in turn to specify the conditions that promote communication characteristics on which we could build in order to support students in using talk to learn with others.

To address the above issues I traced students' attempts in developing shared meanings within eight communication patterns that emerged during a previous research I have conducted on students' intra-group communication while working on computer-based constructive activities (Trouki, 2003). Each communication pattern carries specific communicative characteristics and, therefore, reflects a certain type of peer talk quality. In specific:

- Monologue: One of the group members keeps talking but s/he gets no answer at all even during long pauses that could serve as entry points for others.
- Parallel monologues: Each speaker ignores the others' verbal contribution and continues talking as if no one else had said anything, which in turn results in the absence of rational sequence between successive turns.
- Parallel dialogues: Students exchange comments focusing on the same point, but they move towards it following different paths. It looks like they are moving on parallel tracks and, so, the turns have loose relevance.
- Pseudodialogue: Students hook their comments on a word or a part of the preceding speaker's comments without building on the actual meaning. So, the exchanged comments have a surface relevance under which a different focus is hidden.
- Linear dialogue: Successive turns of the same starting point and focus form a rational sequence, on the base that each turn is a successive step in a sequence of actions.
- Accumulative dialogue: Each speaker contributes in line with the preceding one either by sharing relevant data and illuminating remarks or by answering the question posed by the previous speaker.
- Counter-position dialogue: Each speaker expresses a different point of view and challenges the preceding speaker's position. So, s/he builds on the previous one in order to express an opposite or alternative suggestion.
- Inter-completing dialogue: Each speaker builds his/her contribution on what the previous one said by providing an elaborated version of the preceding turn or by completing the semi-formed phrase of the previous speaker.

Going from monologue to inter-completing dialogue I consider communication patterns to be more complex, based on how successive turns are related to each other. The collected data showed that simple communication patterns do not promote ideas elaboration and revision, as the conversational turns remain isolated "voices" and students exchange comments without taking into consideration what the previous speaker said. On the other hand, the complex communication patterns include communicative acts – e.g. providing alternative ideas, asking for and providing arguments, extending other's ideas – that allow students to reconsider and modify ideas.

This finding is particularly important considering that the identified types of pseudo-communication (i.e. monologue, parallel monologues, parallel dialogues and

pseudo-dialogue) seem to be the symptom of students' incompetence in handling not cognitive but personal conflicts arisen from the group's organization (i.e. roles, rights, and obligations). As long as the responsibility for the common task was centered on the one who was at the keyboard, comments uttered did not elicit responses nor were followed by ideas exchange and negotiation; the keyboard controller took on both the practical and conceptual part of the work and tended to exclude his/her peers. Thus, students focused on gaining or keeping the control of the activity rather on working on ideas and the exchanged comments served as techniques for implicit negotiation of status instead of ideas. Moreover, it was interesting to find that complex communication patterns took place when students had to pause practical work and think on their preceding actions; in such cases participation went beyond the physical manipulation of tools, while ideas exploration and reformulation was promoted.

Taken together, the above findings have implications for both research and teaching practice. First of all, teaching interventions towards successful collaboration are necessary, since shared responsibility and decision taking are reflected in communicative characteristics, which in turn leverage opportunities for ideas revision and meaning negotiation offered by the software. Also, the activity design can play an important part towards this direction. While the exploratory software facilitates ideas expression within a thinking-aloud practice, further discussion and revision of ideas are promoted when the activity design has inbuilt opportunities for ceasing action and reflecting on it.

References

Barnes, D. (1992). The Role of Talk in Learning. In K. Norman (Ed.), *Thinking Voices: The Work of the National Oracy Project* (pp. 123–128). London: Hodder and Stoughton.

Kynigos, C. (1995). Programming as a means of expressing and exploring ideas in a directive educational system: three case studies. In A. diSessa, C. Hoyles, R. Noss & L. Edwards (Eds.), *Computers for Exploratory Learning* (p. 399 - 420). Berlin: Springer Verlag.

Mercer, N. (1995). The Guided Construction of Knowledge: Talk Amongst Teachers and Learners. Clevedon: Multilingual Matters.

Schegloff, E. A. (1991). Conversation analysis and socially shared cognition. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on Socially Shared Cognition* (pp. 150-171). Washington DC: American Psychological Association.

Trouki, E. A. (2003). Students' verbal communication and exploratory learning using Information and Communication Technology. Unpublished PhD Thesis, University of Athens.

Vygotsky, L. S. (1978). *Mind in society: The development of higher mental processes.* M. Cole, V. John-Steiner, S. Scribner & E. Souberman (Eds.). Cambridge, MA: Harvard University Press.

Classroom Science Discourse on Acidity: Towards a Sociocultural Account on Conceptual Change

Ilias Karasavvidis* and George Malandrakis, University of Crete, Greece

Conceptual Change

After two decades of research in science education it has been established that children are active learners who intuitively construct representations of and develop meanings about the physical world with which they interact. These ideas are usually referred to as "children's science", "alternative conceptions", "alternative frameworks", "misconceptions", "conceptual models" etc. As indicated by several studies, these ideas are nothing but neutral as far as formal science learning in schools is concerned, since they influence it. This fact led to the study of these ideas in the context of their change as a function of instruction and to the emergence of the conceptual change approach (for a comprehensive overview see Vosniadou, 1999; Duit, 1999).

In her discussion of how conceptual change can be further advanced, Vosniadou (1999) argued that what is basically needed is a theory of learning which will bridge the two main research traditions related to conceptual change, namely science education and cognitive-developmental. We perfectly agree with and build on her view and provide a first contribution towards that direction.

The call for more situated, contextualized and discursive approaches

Recent criticisms of the existing conceptual change approaches have outlined their limitations and called for for other perspectives, such as relating internal representations to external situated variables (Vosniadou, 1999), the influence of systems of signs on thinking and communication (Nunes (1999), and the discursive nature of conceptual knowledge (Saljo, 1999). More specifically, we agree with Saljo's (1999) call to study discourse, not only because it is all what we have access to but also because, as Holquist (1990) argued, discourse does not merely represent a situation, it is the situation.

A Sociocultural Approach: the 3C Model

The model proposed in this paper has its roots in sociocultural psychology and is principally inspired by the work of Vygotsky (1987). It is also based on current extensions of the Vygotskian framework (Wertsch, 1998) and its applications to educational settings (e.g. Lemke, 1990; Wells, 1999; Mortimer & Machado, 2000).

The objective of the model is to help us represent, understand and study classroom science discourse and, consequently, science conceptual change. This is accomplished through a focus on discourse and the synthesis of multiple perspectives: educational, cognitive, sociological, and linguistic. More specifically, the model synthesizes ideas advanced by Vygotsky (1987) (concept formation, scientific and everyday concepts, relation of words to concepts), Bakhtin (1986)

(voice, genre, addressivity), and Leont'ev (1981) (structure of human activity: activity, action, operation).

The model is comprised of three main components-dimensions (hence 3C): activity, genre, and principle. Given a certain cognitive task, the dimension of activity is related to the actions and operations required to carry it out, the dimension of the genre refers to the specific language and terminology involved, and, finally, the dimension of principle reflects to the overall rationale according to which the actions and operations required for solving the task are performed.

An illustration of the 3C Model

An illustration of the model is provided with the analysis of episodes of fifth grade science discourse on acidity. In an instructional intervention which spanned over 15 class periods a teacher worked with a group of twelve students on the difference between bases and acids. The whole instructional activity revolves around the construction of a pH indicator using red cabbage juice. The students conduct several experiments under teacher supervision and guidance.

Discussion and implications for conceptual change

The appropriateness of the model for analyzing science discourse from a situated, sociocultural perspective is discussed and the pros and cons are highlighted. Particular emphasis is paid to the insights which can be gained by the application of the model to the study of conceptual change compared to the more traditional cognitive or science education analyses. Assuming that students' grasp of the activity, genre, and principle may vary from poor to good, student learning can be described and studied in six different ways. Consequently, this paves the way for the study of the many facets of conceptual change. It is concluded that the 3C model is a potentially interesting descriptive tool for the analysis of classroom science discourse and conceptual change.

References

Bakhtin, M.M. (1986). *Speech genres and other late essays*. (Edited by C. Emerson & M. Holquist, translated by V. McGee). Austin: University of Texas Press.

Duit, R. (1999). Conceptual change approaches in Science Education. In W. Schnotz, S. Vosniadou & M. Carretero (Eds). *New perspectives on conceptual change* (pp. 263-282). Amsterdam: Pergamon.

Hallden, O. (1999). Conceptual change and contextualization. In W. Schnotz, S. Vosniadou & M. Caarretero (Eds). *New perspectives on conceptual change* (pp. 53-65). Amsterdam: Pergamon.

Holquist, M. (1990). *Dialogism*: Bakhtin and his world. London: Routledge.

Lemke, J.L. (1990). *Taking science: Language, learning, and values*. Norwood, N.J.: Ablex Publishing corporation.

Leont'ev, A.N. (1981). The problem of activity in psychology. In J.V. Wertsch (Ed. & trans.) *The concept of activity in soviet psychology* (pp. 37-71). Armonk, N.Y.: M.E. Sharpe.

Mortimer, E.D. & Machado, A.H. (2000). Anomalies and conflicts in classroom discourse. *Science Education*, 84, 424-444.

Nunes, T. (1999). Systems of signs and conceptual change. In W. Schnotz, S. Vosniadou & M. Caarretero (Eds). *New perspectives on conceptual change* (pp. 67-80). Amsterdam: Pergamon.

Saljo, R. (1999). Concepts, cognition and discourse: from mental structures to discursive tools. In W. Schnotz, S. Vosniadou & M. Carretero (Eds). *New perspectives on conceptual change* (pp. 81-90). Amsterdam: Pergamon.

Vosniadou, S. (1999). Conceptual change research: state of the art and future directions. In W. Schnotz, S. Vosniadou & M. Carretero (Eds). *New perspectives on conceptual change* (pp. 3-13). Amsterdam: Pergamon.

Vygotsky, L.S. (1987). The collected works of L.S. Vygotsky. Vol.1: Problems of general psychology. Including the volume Thinking and speech. (R.W. Rieber & A.S. Carton, Eds., N. Minick, Trans.). New York: Plenum Press.

Wells, G. (1999). Dialogic Inquiry. Towards a Sociocultural practice and theory of education. Cambridge: Cambridge University Press.

Wertsch, J.V. (1998). *Mind as action*. NY: Oxford University Press

Using Multi-Modal Representations to Promote Conceptual Change: Theory and Application to Science Classrooms

Linda McGuigan* and Terry Russell, University of Liverpool, UK

Aims

The principle aim of our research has been to explore the possibility of defining (with and through teachers of science in the 5-11 age-range) classroom-viable and theoretically well-founded multi-modal strategies for promoting pupils' science understanding. The particular domain of understanding in which the enquiry was conducted was that of gravitational force.

We have also aimed to develop the theoretical model of Representational Redescription through classroom-grounded activities. Models of conceptual change can be classified as drawing upon two main theoretical traditions: psychological and the socio-cultural, each having certain implications for the kinds of activities assumed to be instrumental in promoting pupils' conceptual change. Our understanding of 'representations' is that they may be both idiosyncratically constructed and socially transmitted or negotiated. We have consequently explored the possibilities of extending RR into a social context, beyond the original description of intra-individual conceptual change. We attempt to link psychological

and socio-cultural perspectives to extend the repertoire of conceptual change strategies that can be made available to a teacher.

Methodology / Research Design

An experimental (n = 260 pupils) and control group (n = 215 pupils) design was used. Working with the experimental group of 10 teachers, strategies to encourage pupils' multi-modal thinking and Redescription were described in principle. Teachers were encouraged to translate principle to classroom-viable practice, bearing in mind the implications for implementation within their classroom ecologies. A repertoire of multi-modal intervention strategies was devised which teachers were actively encouraged to adopt.

Our theoretical starting point was Karmiloff-Smith's (1997) modelling of microgenetic change in terms of Representational Redescription. This states that inchoate (intuitive or naïve) understandings *within* the (mind/brain) system are made available *to* the system through a process of explicitation. Explicitation is a metacognitive, verbally mediated, conscious processing through which an individual becomes aware of his or her own beliefs. Such beliefs would, under most circumstances, remain tacit. Deliberately constructed intervention strategies agreed with teachers required such beliefs to be explicitly articulated and, critically, to be redescribed using alternative representational modalities. Once explicit, those beliefs could be reflected upon and be subjected to checks or challenges. Awareness of the need for conceptual revision (or justifying evidence) was prompted by self-recognised internal discrepancies, inconsistencies pointed out by peers or teachers, or exposure to alternative and conflicting explanations emerging through the forum of classroom interactions.

Conceptual change was examined both microgenetically by reference to qualitative changes in individual children's thinking and macrogenetically, using pencil and paper 'concept probes' (generative questions about various scenarios involving gravitational force). In the latter case, the frequency of a range of ideas expressed (the dependent variable) was measured against the age of respondents (independent variable) expressing those beliefs. The understanding of a control group of pupils was similarly assessed using the same probes; the control group teachers used their usual teaching strategies to address the same national curriculum agenda as the experimental group.

Outcomes

Planning meetings, classroom observations and teachers' reports made clear the different ways in which teachers' implemented multi-modal approaches to promote explicitation and transformation of pupils' ideas across representations. A variety of representational modes was employed including drawing, writing, speech, kinaesthetic experiences and use of three-dimensional modelling. Macro- and micro-developmental data revealed some of the impact of these approaches on learning outcomes.

The application of RR and cross-modal strategies was associated with significantly enhanced conceptual change in the direction of conventional scientific understanding amongst the experimental group as compared with the control group. Drawings illustrating the action or effects of gravitational force, together with written explanations, showed significant differences when pre- and post-intervention ideas were compared. For instance, a significant increase in representing a plumb line as hanging towards the centre of the Earth was recorded amongst the Research group ($p<0.001$). Prior to intervention, only half of the experimental sample drew the plumb line oriented in this direction, this proportion rising to 90% following intervention.

Theoretical and educational significance of the research

As applied educational researchers, we find the significant gains in understanding manifest by the pupils who engaged in cross-modal representational activities extremely encouraging. The approach makes sense to teachers at the level of professional praxis; the language of encoding and decoding speech to text is familiar to many. Educationally and pragmatically, there are exciting leads to follow – particularly the possibilities of teachers themselves identifying and applying domain-specific cross-modal strategies across the curriculum. From the point of view of psychological theory, if not resolved, the problems are clearer. For example, there is a need to clarify what exactly is a mode or modality. While persuaded about the utility of the notion of explicitation as a process that brings what is known intuitively to conscious awareness, we are led to speculate about the unique centrality of the linguistic mode in serving metacognitive awareness (as asserted by Karmiloff-Smith o*p. cit.*). For example, we have long advocated the drawing of ideas by pupils as representations of beliefs that lend themselves to social transactions involving knowledge claims and justification. The role of interactions around representations, including challenges to their validity or applicability, adds an important social dimension to RR's classroom application.

References

Karmiloff-Smith, A. (1997) Continuing commentary on Beyond modularity: a developmental perspective on cognitive science. *Behavioral and Brain sciences*. 20, (2) pp 351-369.

Kress, G; Jewitt, B; Ogborn, J and Tsatsarelis, C. (2001) Multi-modal teaching and learning: the rhetorics of the science classroom.

Lemke, J L (2003); *Teaching all the languages of science: words symbols, images and actions*. http: /www-personal.umich.edu/~jaylemke/papers/barcelon.htm

Russell, T and McGuigan, L (2002); Promoting understanding through representational Redescription: an illustration referring to young pupils' ideas about gravity. In Psillos, D, Kariotoglou, P; Tselfes, V, Hazitkraniotis, E; Fassoulopoulos and Kallery, M (Eds.) *Science education research in the knowledge-based society*. pp. 61-68. Kluwer academic publishers

Vosniadou, S (2001) Conceptual change Research and the teaching of science. In Behrendt et al. (Eds.) *Research in science education – Past, present and future*, pp.177-188. Kluwer academic publishers.

Literacy acquisition in Greek: the Role of Phonological Awareness and Socio-Economic Status

Athanasios Aidinis, School of Education, Department of Primary Education, Aristotle University of Thessaloniki, Greece

Introduction

Literacy acquisition is described as a developmental process during which different skills and strategies are acquired and used. For a number of researchers this developmental pathway starts from emergent literacy, emphasizing the active role of children in discovering and learning about literacy through their own attempts at reading and writing (Ferreiro, 1986; Clay, 1992; Teale and Sulzby, 1986). According to this view, emergent literacy leads directly to conventional literacy (Senechal et al., 2001) and includes all the behaviors and concepts that precede and develop into conventional literacy (Sulzby, Branz and Buhle, 1993). On the other hand, it is suggested that emergent literacy is the first phase in literacy acquisition followed by a second early literacy phase and is completed in the third phase of conventional literacy (Chall, 1983). In this perspective, children's literacy behaviors, the environment in which these behaviors occur and the link between the above two are examined (Purcell-Gates, 1996; Payne et al., 1994; Senechal et al., 1996) in an attempt to clarify how and under what conditions children's ideas and skills related to literacy develop. One of the skills, that is strongly related to learning to read and write, is phonological awareness (Adams, 1990; Hulme and Ellis, 1994; Goswami and Bryant, 1990; Bryant, 1998). According to recent findings in research on literacy acquisition, phonological awareness is not a unitary concept but consists of different levels that explain the variance of phonological awareness tasks (Muter et al., 1998; Wagner et al., 1994). It is also suggested that these different levels or factors of phonological awareness, which are related both to different levels of complexity of phonological skill (syllables, phonemes, onset-rime) or to qualitatively different phonological abilities (explicit or implicit knowledge), have different contributions to reading and spelling (Muter et al., 2002; Ellis, 1988; Karmiloff-Smith, 1987). There are also studies that are trying to explain the variance of phonological awareness tasks on the basis of differences on the socioeconomic status (Bowey, 1995; Raz and Bryant, 1990).

Taking into account these findings, the present study examines whether phonological awareness consists of different levels in Greek language and the relation of these levels to the reading and spelling abilities. The shallowness of the Greek language, the constant relations between graphemes and phonemes and the clear syllabic structure might differentiate the levels of phonological awareness exist in Greek and their relation to reading. Is there a particular level of phonological awareness that children must have acquired in order to learn to read and spell? Spelling Greek is a different task. The phoneme – grapheme correspondences are not constant and the use of a phonological strategy in spelling results to a number of spelling errors. The second question that the present study addresses concerns with the nature of the relationship between phonological awareness or different levels of phonological awareness and spelling. The difference between reading and spelling in Greek is also examined. Lastly, the question of whether differences on socioeconomic status affect the development of phonological awareness, reading and spelling is also investigated.

Method

In order to examine these questions, 81 six and seven years old children were given four different phonological awareness tasks (a syllable oddity task, a phoneme oddity task, a syllable deletion and a phoneme deletion task). These tasks differ both on the complexity of the phonological skill and the phonological ability they require. A task of reading and spelling words and pseudowords of different level of difficulty in respect to the orthographic patterns they included, was also used. The words were the same for the reading and the spelling task so that a comparison between the two to be made. Lastly, a questionnaire was given to the parents of the children, including questions concerning home literacy activities such as book reading, story telling, learning the names or the sounds of the letters etc. Information about the educational level and the occupation of the parents was also gathered.

Results

The results showed that there are two different levels of phonological awareness (one for phonemes and one for syllables). The two levels explain different amounts of variance in reading and spelling and they have different significance in different ages. These results show that in an alphabetic system with clear syllabic structure, phonological awareness at the level of syllable plays an important role in reading and spelling. This role is different at different age levels. Socioeconomic status was also significantly related to phonological awareness and to reading and spelling, showing that home literacy activities have an effect on the development of phonological awareness, reading and spelling.

Discussion

This study showed that there is a strong relation between phonological awareness and reading and spelling. Furthermore, it showed that phonological awareness is not a unitary concept but consists of different levels that play a different role on reading and spelling, and this role is different for different ages. The relationship found between socioeconomic status and children’s phonological ability shows that children’s home literacy environment plays a significant role on the development of this type of metalinguistic ability. However, it is not clear from the present study

what aspects of this literacy environment influence children’s ability. In addition, research is needed on how we can construct learning environments in school in order children to get the useful information in relation to home literacy environments which will allow them to transform their ideas and knowledge about the written language in order to acquire conventional literacy.

Thursday, May 20th

08.30 - 11.00: Keynote Addresses & Panel Discussion

Chair: Erno Lehtinen, University of Turku, Finland

Keynote Addresses

In the Wake of Kuhn's Theory of Scientific Revolutions

Lillian Hoddeson, University of Illinois at Urbana-Champaign, USA

In the early 1960s, the emerging field of history of science felt the explosive impact of a new theory put forth by one of its new members, Thomas S. Kuhn, a convert from theoretical physics. While the history of science was adjusting to Kuhn over the next several decades, other fields interested in conceptual change (including philosophy, sociology, and science education) were also responding with reformulations of their intellectual frameworks.

When the blast passed, scholars in the fields that had been hit, reflected on problems left behind in the wake of the Kuhnian wave. Why were most of the conceptual changes in each field not nearly as sudden as Kuhn suggested? Why did the Kuhnian picture of "normal science," "anomalies," "revolutions," new paradigms, and so forth, not fit most changes as neatly as Kuhn had described when he wrote about the transition to quantum mechanics or the Copernican picture? How could the elegant Kuhnian framework cope with such messy and contingent issues as gender, race, patronage, or politics? And how was one to deal with the fact that in dealing with his critics Kuhn had by the end of his career destroyed the crispness of many of his earlier notions, including paradigm and normal science? It is certainly true that many scholars in fields outside the history of science took Kuhn's theory far more literally than Kuhn ever intended it to be. This valid disclaimer however avoids answering an important question: Is there still any use in Kuhn's theory of scientific revolutions? This talk will try to show how Kuhn can still help scholars who study conceptual change.

The Situated Character of Model-Based Reasoning in Science

Nancy Nersessian, Georgia Institute of Technology, USA

For over twenty years now there has been a movement in the field of cognitive science towards developing an account of cognition that incorporates the environment (social, cultural, material) into analyses of cognitive processing in a non-reductive manner. These analyses make *action* the focus for understanding

human cognition; thus they take as their starting point questions about how human actors think in complex social, cultural, and material environments. The proponents of such 'environmental perspectives' have emphasized that cognition is *embodied* (See, e.g., Lakoff & Johnson, Barsalou, Glenberg), *enculturated* (See, e.g. Nisbett, Tomasello, Donald, Shore), *distributed* (See, e.g., Hutchins, Norman, Zhang), and *situated* (Lave, Suchman, Clancey, Greeno). Here, for simplicity, I will refer to all of these perspectives as championing the 'situated' character of cognition - a feature that cuts across the perspectives. In this paper I want to consider the ramifications of thinking about cognition as situated for understanding the model-based reasoning practices of scientists.

Scientific practices are prime candidates for examining the role of the environment in cognition. Clearly the accumulated wisdom of much contemporary history, philosophy, and sociology of science establishes the central importance of the social, cultural, and material environments in which these practices develop and are employed. Much cognitive-historical research, in particular, argues for the centrality of the environment to explanations of the cognitive practices of scientists (See, e.g., Nersessian, Gooding, Tweney, Giere). However, this research, until quite recently, has not utilized environmental accounts of cognition in developing the cognitive bases of the scientific practices. In previous work I have argued that specific kinds of model-based reasoning practices, viz., analogical modeling, visual modeling, and thought-experimental simulation are modes of reasoning that are generative of conceptual change in science. Central to that analysis is the notion that the human capacity for mental modeling provides a cognitive basis for these practices. Here I will develop an account of mental modeling as situated reasoning, compatible with the situated perspectives on cognition. The situated character of model-based reasoning will be examined in two cases, one that comparatively examines an expert problem-solving protocol and historical case of conceptual change, and one that examines ethnographic data of a research laboratory where model-based reasoning is conducted using physical simulation devices.

Panel Discussion

Theodore Arabatzis, University of Athens, Greece
Mario Carretero, Universidad Autónoma de Madrid, Spain
John Clement, University of Massachusetts, USA
Konstantinos Gavroglou, University of Athens, Greece
Anna Sfard, University of Haifa, Israel
Betty Smokovitis, University of Athens, Greece

11.30 - 13.30: Paper Sessions

A. Teacher Education in Conceptual Change

Chair: Margarita Limón, Universidad Autónoma de Madrid, Spain

Discussant: Noel Entwistle, University of Edinburgh, UK

Evolution of Primary School Teachers' Practices and Conceptions in Context of ICT-Related Professional Development

Colette Deaudelin*, Université de Sherbrooke, Monique Brodeur, Université du Québec à Montréal, Marc Dussault and Sonia Lefebvre, Université du Québec à Trois-Rivières, Julien Mercier, Université McGill, and Jeanne Richer, CEGEP de Trois-Rivières, Canada

In Canada and the United-States notably, many recently developed curricula regarding primary and secondary school levels identify a set of ICT-related competencies that students must develop (Karsenti, Brodeur, Deaudelin, Larose, and Tardif, 2002). However, the low degree of use of ICT by primary and secondary school teachers noted in many sources (Conseil Supérieur de l'éducation, 2000; Ravitz and Wong, 1999) is likely to compromise the development of such skills. These curricular changes show the importance of continuing research about the process of ICT implementation in schools, notably about the in-service training programs offered to teachers linked to their professional development. Teachers' in-service training programs are often found incomplete. Thus, we often note the inefficacy of these programs (Cohen & Hill, 2000), the scarcity of empirical evidence concerning their effect on teachers' practices and on students' learning (Garet, Porter, Desimone, Birman, and Suk Yoon, 2001) and the precariousness of the changes they permit (Guskey, 2002). Wilson and Berne (1999), show that few studies concern the efficacy of in-service training programs, the studies being more concerned about the satisfaction of teachers participating in such programs than their learning.

Aim

This presentation describes a study that aims at: Developing a in-service training strategy in collaboration with primary school teachers; Analyzing the ITC-related learning of primary school teachers, made possible by this in-service training strategy. As shown in the conceptual framework presented next, this learning is examined from the point of view of teachers' practices and their conception of teaching, learning and ICT.

Conceptual framework

Being interested in teachers' learning in an in-service training context is, in fact, examining their professional development. According to Guskey's (2002) model, we can argue that a teacher's professional development is expressed by a change in his thinking and his practices.

Among the concepts used to refer to teachers thinking (belief, social representation, and conception), we choose the notion of «conception». This notion permits the study of a construct that is individual rather than collective, and the work on conceptual change provide to this end a good theoretical basis. The term «conception» designates here a set of concepts and the relations between them (Hoz and Yukhnovetsky, 2001). The term "practice" refers to teaching practice, defined in reference to Altet (2002) as the teacher's singular and finalized acts, realized at the pre-active, interactive and post-active phases of his intervention with students. During the pre-active et post-active phases, where acts are more hardly observable, a "declared" practice will be studied, while the practice will be observed during the interactive phase.

Conceptions and practices have been examined from a conceptual framework identifying two major perspectives of learning: social behaviorism and neoconstructivism. Indeed, many studies converge towards the identification of two perspectives or philosophies in relation to practices of ICT implementation (Becker and Riel, 2000; Niederhauser and Stoddart, 2001): a traditional philosophy of education based on the transmission of knowledge often associated to behaviorism and a philosophy compatible with constructivism centered around knowledge construction.

Method

Subjects: Forty teachers working in five primary schools of a Québec (Canada) school board participated in this action research that lasted three years. Eight of them volunteered to participate in interviews and accepted to welcome an observer in their classroom.

In-service training strategy

The in-service training strategy developed hinges on numerous studies related to in-service training programs related to teachers' professional development (Deaudelin, Brodeur, and Dussault, 2001). It also takes into account variables neglected in many in-service training programs: self-regulated learning, self-efficacy and organizational commitment. The strategy put a particular emphasis on characteristics likely to induce conceptual change (Hewson and Macbeth, 2000; Tyson, Venville, Harrison, and Treagust; 1997; Vosniadou, Ioannides, Dimitrakopoulou, and Papademetriou, 2001).

The in-service training program consisted of 12 meetings for each participating school. Nine meetings (2h/each) where centered around the development of teaching and learning projects aiming at an increased use of ICT and three focused on the development of technical skills according to the needs arising from the projects being developed.

Data collection and analysis

Data were collected, at the beginning and the end of the training (a 5-month interval), by means of interviews and observations conducted with eight volunteers. Semi-structured interviews were conducted using a guide containing open-ended questions inviting each teacher to express herself about: his conception of teaching, of learning and of ICT; the acts characterizing his practice during the pre-active, interactive et post-active phases ("declared" practice).

Regarding observed practices, two observation sessions were conducted following the interviews at the time chosen by the teacher. The observation was conducted using a guide taking into account the following elements of the teachers' practice : social resources (students, teachers or others), ICT and time exploited, the task during the observation session, the manner in which the content is presented, and the feedback given.

The analysis framework takes into account process variables (communication dynamics, teacher's and student's roles, learning dynamics, external or internal regulation process), variables related to devices (tools and medias used, organization of time and space) and variables related to contents (choice of learning objects and activities) (Bru, 1993). For each of these variables, indicators have been specified according to the two perspectives retained: social behaviorism and neoconstructivism.

Results and discussion

Results show that the teaching practices observed, related in majority to social behaviorism, have evolved towards neoconstructivism for four of the six teachers for whom the practices have changed. Declared teaching practices are also mainly related to social behaviorism for six of the eight teachers. Their evolution operates equally towards neoconstructivism, social behaviorism or other perspectives. Finally, regarding the conceptions, the situation is even more diverse. Five of the teachers expressed conceptions associated with other perspectives while two others expressed themselves in terms of neoconstructivism. The evolution proceeds in various ways.

The discussion presents an analysis of the results based on the context of the study, the work on conceptual change and models linking teachers' thinking and practice. Future directions are suggested for research and professional development.

Co-Inquiring with Teachers the Ways of Teaching Science: From a Conceptual Change to a Discourse Change Perspective"

Panagiotis Piliouras* and Panagiotis Kokkotas, University of Athens, Greece

Introduction-Aims

This paper refers to the first results of an action research program. The purposes of this program are: (a) to identify the pedagogical strategies necessary to create a collaborative inquiry learning environment in elementary science classrooms, (b) to evaluate the extent to which properly designed lessons that adopt these pedagogical strategies can change the nature, the type and the quality of dialogues that take place during the science lessons.

Theoretical and educational importance

A common way of understanding the difficulties students encounter in trying to understand a scientific concept is to regard the problem as being one of conceptual change (Halden 1999). Conceptual change approaches to the teaching and learning of science have been enormously influential for almost two decades in science education (Limon & Mason 2002; Schnotz, Vosniadou, Carretero 1999).

In recent years, the theoretical frameworks underpinning the views of learning, language and cognition gradually have shifted from a personal constructivist view towards more socio-cultural (Lemke 2001) and discursive views (Cowie & van der Aalsvoort 2000).

On this emerging theoretical and research perspective, the problem of learning is not how to bring about a conceptual change, but rather how to create a situation where the appropriate scientific ideas will come into play (Halden 1999). According to Saljo(1999), a learner's insufficient capability to apply scientific concepts is not caused by misconceptions, but results from insufficient access to authentic discursive practices in which scientific concepts are functional. This perspective offers an interpretation that is complementary to classical conceptual change, treating experience not as knowing but as meaning and hence as something that is construed in language.

In science education, the conceptual change pedagogical practices of the classroom have been challenged by the notions of communities of inquiry (Roth 1996), in which emphasis is placed on collective meaning-making and inquiry-based activities (Wells 1999). The argumentative and discursive aspects of teaching and learning scientific concepts and practices have lead educators to define science as discourse. This view of science as a discourse helps us to see scientific literacy not as the acquisition of specific facts and procedures or even as the refinement of a mental model, but as a socially and culturally produced way of thinking and knowing, with its own ways of talking, reasoning, and acting.

However there are difficulties in establishing the desirable dialogic environment in science teaching classrooms. The reason is that teachers lack the competency to implement effective discourse and collaborative inquiry activities. Therefore, we conduct an action research program that aims to transform teachers' and students' perspective to teaching and learning as a collaborative inquiry mode and to a dynamic process of progressive appropriation of science dialogues and practices. One basic issue examined in our approach is the way action and meaning in science teaching practice changes as discourse changes.

Research design

Our research is based on a collaborative action research framework. The research takes place in two phases. In the first phase, initially, we conducted a thorough review of literature in science teaching as collaborative inquiry. Afterwards, we created a group of twelve teachers interested in collaborating with us in order to develop their understanding of our theoretical approach to dialogic and inquiry nature of learning science. In the second phase we will apply the successful strategies in order to create a collaborative inquiry environment. For every teacher-researcher, we gather a large amount of data including video and audio-recordings of classroom events. For analyzing the data, among other research tools, we use a three-dimensional descriptive system of analysis proposed by Kumpulainen and Mutanen (1999).

Results

The study and analysis of data that we made with the active participation of the teacher-researchers indicates that teachers, before they get familiar with and develop the proper theoretical and practical background, lacked essentials skills and competencies to cultivate a collaborative learning environment, and a dialogic mode of meaning making.

The most teachers used dialogue but in a monologic and univocal way, adopting implicit or explicit conceptual change perspectives. The major type of interactive sequence was one-dimensional and monolithic. In most of the cases teachers determined exclusively the theme of discourse, using a variety of control strategies to maintain thematic control. As far as it concerns students, they lacked the competency to cooperate and to work together. The nature, the type and the quality of student discourse have not the desirable characteristics for collaborative inquiry learning.

The heretofore evolution of our research indicates that the implementation of our overall scheme enhances the quality of social interactions in science classrooms and lead to the gradually but slow transformation of classrooms. They gradually become more dialogical and less authoritative and implement strategies that support childrens' meaning making.

Conclusions and implications

Changing school culture and classroom practice isn't an easy work. Our study indicates that the process of transformation of a learning environment is a slow and

vigorous procedure that needs teacher's considerable experience with new pedagogical strategies. In our opinion, effective teaching transformation to a discourse change perspective it is possible to be achieved when teachers have opportunities to investigate and experience the overall effort within a collaborative inquiry framework.

References

Halden (1999); Conceptual Change and Contextualization. In Schnotz, Vosniadou & Carretero (Eds.): *New Perspectives on Conceptual Change*. Oxford: Elsevier.

Limon & Mason (Eds.) (2002); Reconcidering conceptual change–Issues in theory and practice. Dordrecht: Kluwer.

Schnotz, Vosniadou & Carretero (Eds.) (1999). *New Perspectives on Conceptual Change*, Oxford: Elsevier.

Saljo(1999). Concepts, cognition and discourse: From mental structures to discoursive tools. In Schnotz, Vosniadou, & Carretero (Eds.): *New Perspectives on Conceptual Change*. Oxford: Elsevier.

Cowie & van der Aalsvoort (Eds.)(2000). Social interaction in learning and instruction. The meaning of discourse for the construction of knowledge. Pergamon.

Lemke(2001) Articulating Communities: Sociocultural Perspectives on Science Education. Journal of Research on Science Teaching 38(3): 296-316.

Wells(1999). Dialogic Inquiry. Toward a Sociocultural Practice and Theory in Education. Cambridge University Press.

On the Extent of Grasping Some Ideas behind Formulas in Science: a pilot study among students at the edge to become professional secondary school teachers.

Helge Strömdahl, Royal Institute of Technology, Sweden

Aim

The aim of this study is to find out to what extent teacher trainee students has reached a level of coherent conceptual understanding of some fundamental ideas of physical quantities, quantity calculus and mathematical modeling, in common words "the ideas behind formulas".

Methodology / research design

This is a pilot study comprising 4 teacher trainee students (age~30) at a 3½ year teacher trainee program in science and mathematics for the secondary school level (age 0-6) at a university in Sweden. The data collection was done about a month before they finished the program (December 2003) and after that supposed to act as professional teachers. Data is collected via individual videotaped interviews, shaped as dialogues about teaching and learning science. Questions aiming at trigging the interviewees to reveal their conceptions around the current subject were smoothly phased into the interview.

The interviews were contextually analyzed resulting in statements illustrating the students' overt conceptual status around the current subject.

The study is built on the general assumption that it is important for the professional teacher to have deep disciplinary knowledge of fundamental ideas when teaching school science (cf. Ma, 1999).

Outcomes

All students are emotionally aroused, frustrated and show low self-confidence when formulas and mathematics were brought up in the interview. On the contrary they were talking with great confidence on general pedagogics concerning to teach from the pupils' perspective, experimental work and motivating pupils to become interested in science by referring to 'reality'.

Results

- None of the interviewees recognize the general gas equation pV= nRT and can fully identify the symbols in the formula.
- Two interviewees remember Ohms law U= RI and identify the symbols, one remember Einstein's formula E= mc^2 and one can not remember any formula.
- "Physical quantity", "quantity calculus" and "mathematical modeling" lack substantial meaning and are no active terms in the interviewees' reasoning
- The awareness of SI and SI units is low. None can tell correctly which or how many the basic units are.
- Knowledge about the mathematical structures behind formulas is low and uncertain.

In summary, none of the four students at the edge to act as secondary school teachers has attained a conceptual change to be able to reason professionally about some essential ideas behind formulas.

Theoretical and educational significance

Most of science education research studies where "formulas" are in focus have dealt with problem-solving and differences between novices and experts (eg. Savelsbergh, de Jong, & Fergusson-Hessler, 2002). The extensive research on students and teachers conceptions of scientific concepts (Duit, 2004) is not explicitly directed towards concepts as physical quantities (Strömdahl, 1996b, 1998, 2003). An example of the significance of focusing SI and physical quantities to sort out conceptual obstacles in science education is demonstrated in Strömdahl, 1996a. Furthermore, some studies have dealt with the important idea of idealization in science and about scientific language use (e.g. Song et al., 2001; Ragout de Lozano & Cardenas, 2002). Among others, Nersessian (e.g.1992) has from a perspective of

philosophy and history of science pointed out the educational benefits to draw upon the disciplinary evolvement of mathematical modeling of physical phenomena. By possessing such knowledge the teacher has a disciplinary basis and fundamental PCK for designing instructional sequences adapted to the current group of students.

How can the results from this pilot study be interpreted? Is it depending on insufficient training in disciplinary science during the educational program? Has no special attention been directed to the specific content area dealt with in this study? Or, has sufficient information been present but the students have not been able to make a conceptual synthesis and conceptual change into mastering the current subject content? Is there a fear in teacher education for 'traditional formula physics' that is often viewed upon as obsolete and has nothing to do with "pupils reality", especially when the school educational intention is "scientific literacy"? Is this fear an unconscious mix up of what kind of disciplinary knowledge the teacher ought to possess with what the teacher ought to teach? These questions make up a starting-point for further research.

References

Duit, R. (2004). Bibliography – *STCSE- Students' and Teachers' Conceptions and Science Education*. http: //www.ipn.uni-kiel.de/aktuell/stcse/stcse.html

Nersessian, N. (1992). Constructing and instructing: The role of "abstraction techniques" in creating and learning physics. In R. Duschl, & R. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice* (pp. 48-68). Albany: State University of New York Press.

Ma, L. (1999). Knowing and teaching elementary mathematics. Teachers' Understanding of Fundamental Mathematics in China and the United States. Mahwah, New Jersey, London: Lawrence Erlbaum Associates Publishers

Ragout de Lozano, S. & Cardenas, M. (2002). Some learning probblems concerning the use of symbolic langauage in physics. *Science & Education,11*, 589-599.

Savelsbergh, E.R., de Jong, T., & Fergusson-Hessler, M.G.M. (2002). Situational knowledge in physics: The case of electrodynamics. *Journal of Research in Science Teaching, 39*, 10, 928-951.

Song, J., Park, J., Kwon,S., Chung, B. (2001). Idealizations in Physics: Its types, roles, and implications to physics learning. In R. Pinto & S Surinach, S. (Eds.) *Physics Teacher beyond 2000* (pp 359-366). Paris: Elsevier.

Strömdahl, H. (1996a). On mole and amount of substance. A study of the dynamics of concept formation and concept attainment. (Göteborg Studies in Educational Sciences, 106). Gothenburg: Acta Universitatis Gothoburgensis.

Strömdahl, H. (1996b). *A* commentary on the attainment of the scientific concept energy. In O. Eskilsson & G. Hellden (Eds.) Proceedings of the 5th Nordic Conference on Research in Science Education, March 18-22, 1996, Kristianstad, Sweden.

Strömdahl, H. (1998). Fenomen och egenskap – de fysikaliska storheterna i didaktisk belysning. *Svensk Pedagogisk forskning 3,* 2, 104-112. (Eng. *Phenomenon and property – the physical quantities elucidated*. English summary p.159-160)

Strömdahl, H. (2003). *Modeling conceptual attainment of physical quantities*. Paper presented at the ESERA conference, Nordwijkenhout, The Netherlands, August 19-23, 2003. b

Linking an Instructor to a Teacher: A Factor Motivating towards Change or Causing a Feeling of Incapability?

Sara Kleeman, Academic College of Education, Israel

This paper examines the extent that instruction of teachers by expert peers increases motivation, as reflected in events reported by the instructors themselves. The research presented here will be based on the instructors' case studies. In analysing the studies, it was found in many cases that the instructed teacher often interpreted the linked instructor as a hint that he/she was "not good enough." In other cases, the instruction caused a feeling of incapability and/or the development of dependency. Based on the instructors' testimonies, the instruction was intended to increase motivation towards change and improvement but the opposite results were obtained.

Method

The research used two main tools:

1. A survey among the instructed teachers to examine their relationship to the instruction they received.
2. An analysis of the content of the instructors' case studies.

Target Population

Teachers and kindergarten teachers in the Israeli educational system. These teachers receive instruction in diverse areas by veteran teachers who specialise in certain areas (i.e., mathematics, technology, children with special needs). The Oranim School of Education, Israel, enables teachers serving in instructional roles to specialise and make their instructional activities more professional and firmly based on professional knowledge. Over a two-year period, teacher educators receive instruction in 4-hour sessions held once every two weeks. Within this framework, the teacher educators are given the opportunity to present events from their teaching experiences, and with the help of the group and the mentor, analyse them and focus the discussion on a certain issue or problem. Cases selected randomly from the case studies presented by the instructors represent the basis for this research.

Findings

At this stage, several phenomena may be identified even though the analysis of the texts has not yet been completed:

1. The instructed teachers tend to develop dependency upon the instructors.
2. The instructed teachers interpret the fact that they are forced to receive instruction as an expression of dissatisfaction of their work by the school administration or supervision.
3. Instructors report on a lack of motivation on the part of the instructed teachers and unwillingness to introduce change into their work.

Internationalization in the Swedish Nurse Education from the Perspective of Teachers Involved: An Interview Study

Lennart Svensson, and Monne Wihlborg Lund University, Sweden

Background & Aim

In Sweden the government has increased the emphasis on the international dimension of higher education and enjoined universities and university colleges to take responsibility in developing education in relation to the international development (Jarvis 1996; Knight 1999; Kälvemark & Van der Wende 1997; Van der Wende 1996; Waters 1996).

Therefore an empirical study which aims to investigate teachers' experiences and practices from a curriculum and didactic perspective has been carried out. The overall purpose was to reveal and describe teachers' understanding of internationalisation in teaching and learning within the educational context of the Swedish nurse education as a part of higher education. The results are described in terms of teachers' ways of experiencing internationalisation in teaching and learning and their didactical awareness seen in relation to the wider contextual background of higher education.

In all 18 teachers in nurse education participated in this study, 17 women and one man. They had all participated in a previous survey study (Wihlborg, 2003) [A 28-page self-administered questionnaire containing 23 main questions, and 184 items, if including all follow-up questions] which involved questions to 60 teachers concerning internationalisation in nurse education. The teachers were all teaching at university in Sweden. Semi-structured qualitative interviews were conducted over a period of three months in year 2000. All 18 cases were included in the study but nine of those cases, eight females and one male, were more thoroughly analysed. First, all of the interviews were listened through. Then the nine cases were chosen to be transcribed in their full length. The criteria for selecting the nine cases were mainly to include a wide range of various experiences of teaching matters/issues/topics and areas connected to internationalisation.

The computer program NVivo, a software program for qualitative data processing (Richards, 2000) was used when generating categories, subcategories and codes. Main parts of data were, firstly data on teachers' general understanding of internationalisation and the learning of internationalisation, secondly what content teachers were relating to and teaching when internationalisation was focused within the educational program, thirdly how they taught internationalisation in the nursing program and finally how the teachers described the students' learning outcome concerning internationalisation considered to be achieved within the learning context.

Result

An important background for understanding the results is that the teachers represent, a very selected group on the basis of their interest in and engagement for internationalising nurse education and for increasing intercultural teaching and learning. Thus they are not representative of teachers in nurse education in general. On the contrary they are the most involved and the most knowable teachers, when it comes to internationalisation in nurse education in Sweden. Themes of importance in the results were; *desirable nursing competences, intercultural/socio-cultural competence, forms of teaching and studying, personal experiences.*

Discussion

The results have been presented in a certain order from what the teacher said about, desirable nursing competences, intercultural/socio-cultural competence, forms of teaching and examination, to personal knowledge and experiences as educational content. This is a line from the general aim and expected result to specific content, which also represents a line from what is seen as common and shared to what is varying. In one sense variation is to be expected when going from the general to the specific. Still the picture given through the results is problematic from a curriculum perspective, because it is not a picture of how the more general aim is expressed in the specifics, and then by necessity with variation, within the frame of a common curriculum and didactic thinking. It is rather a picture of that the general aim is connected to different specific contents in a rather accidental way.

Teachers connected internationalisation to some parts of the education, courses they themselves were involved in and that represented specific content areas. These areas varied a lot between the teachers from philosophy, sociology, and public health to specialities like, maternity welfare, obstetrics and geriatrics. Even if they were making a lot of comments about the education in general, they were not relating to internationalisation in the nurse education program as a whole. The exchange programs in use were very little commented on in relation to desirable capacities and intercultural competence.

Based on the results from both the survey study and the interviews, it is held that internationalisation in teaching is more teacher based than curriculum based. The teachers choose the aspects of internationalisation to be elaborated on from their own knowledge and experience. One conclusion from this is that each educational unit, within the Swedish nursing program, when it comes to internationalisation, is rather dependent upon the individual teachers' enthusiasm, knowledge, experience and their spontaneous expression of these in different courses and activities.

All the teachers were well aware of the intentions of internationalisation expressed in guiding documents and of internationalisation as a goal for the education of nurses. However, they missed a discussion of what this intention and this goal means and includes, and also a plan for how internationalisation is to be achieved in teaching and studying. They connected the intention and goal of internationalisation to other general and more established goals of the education and put it in the context of the aim to educate towards a humanistic, democratic and holistic understanding of and approach to patients in nursing.

Personal intercultural knowledge and experiences was the specific content most talked about as content related to internationalisation of the education. The specific content is depending on what happens to be the teachers background and experience. At the same time internationalisation is seen as a matter of some general capacities which have the character of attitudes and approaches in nursing. They are assumed to be promoted through forms of teaching involving reflection and discussion. These capacities are seen as central to and promoted through intercultural competence. The approach to internationalisation expressed includes assumptions about relations between general nursing capacities, intercultural competence, forms of teaching and content in forms of stories that may be questioned. What seems to be needed is more of an understanding of internationalisation, including those relations, as part of students learning.

Epistemological Beliefs of Primary School Students and Their Teachers and Their Effect on Conceptual Change

Florian Haerle, Carl von Ossietzky Universität, Oldenburg, Germany

Theoretical Framework and Educational Significance

Personal epistemology, a field within philosophy, investigates the phenomena of human knowledge, knowing and learning, and their acquisition. The investigation of the epistemological beliefs of individuals is a recent focus area, carried out mainly by researchers in education and psychology (Hofer & Pintrich 2002). Most of the research undertaken thus far has been focused on University and Secondary School students, as the ability of Primary School students to both have epistemological beliefs and be able to verbalise these has been denied (Chandler et al., 1990 quoted in Elder, 2002; Kuhn & Weinstock 2002). However, new research studies published since 2002 state that Primary School students begin to develop epistemological beliefs right from the beginning of their schooling, with their conceptions increasing in complexity with increasing age (Elder 2002 and Schommer-Aikins 2002).

According to Hofer & Pintrich (2002), students' personal epistemological beliefs have a significant influence on their cognitive processes of thinking and learning and students are influenced by the epistemological beliefs of those surrounding them (Elder, 2002). Therefore, it is of high educational significance to deepen our understanding of epistemological beliefs of Primary School students so that training strategies can be designed, and learning environments provided, that will not only enhance the conceptual change of Primary School students but will also advance the epistemological beliefs of both students and teachers. This is a significant issue for teacher learning and development.

Research Aims

The research aims are:

- To understand the epistemological beliefs about knowledge and knowing of Primary School students; and
- To investigate the impact on Primary School students of: teachers' epistemological beliefs and their implemented teaching and grouping strategies.

Research Methodology

The epistemological beliefs of Primary School students and their teachers were gathered using semi-structured interviews to obtain their personal conceptions. The data-gathering process comprised different steps: content analysis, structure analysis and verbal validation of the gathered data. Different software programs were used to support this process.

The classroom teachers were also asked to participate in a second interview in order to investigate their assumptions about the epistemological beliefs of their students. They were asked how they thought their students had answered the interview questions. In order to facilitate the comparison – the two teacher interviews and student interviews - the same research methodology was applied. This also allowed the methodological restrictions of the data triangulation to be minimised.

Sample

Non-random sampling was initially used to select ten classes and their class teachers so as to incorporate the greatest diversity of teaching and grouping strategies. Each teacher was asked to select a mixed ability group encompassing an even distribution of male and female students to be interviewed. 98 Primary School students (boys, n = 50; girls, n = 48) who had had four years of schooling were interviewed along with their classroom teachers (n = 10). A percentage of students with special learning needs (18 %) were also included. All students and teachers participated in the research study voluntarily.

Results

In contradiction to traditional assumptions, such as the generic epistemology of Piaget (1950), preliminary results show that Primary School students by the age of ten do, in fact, have epistemological beliefs and are able to express them. This significant finding confirms the research results of Chandler et al. (2002). However, the teachers being interviewed underestimated their students' epistemological beliefs.

Most of the Primary School students did not consider their teachers as being omniscient authorities and believed that any human can be mistaken. This finding greatly contributes to the debate as to whether Schommer's five beliefs (1990, 1994) constitute epistemological dimensions (Hofer & Pintrich 1997, 2002), in particular the dimension of omniscient authority. Some students, in particular low achieving students, seemed to have more sophisticated strategies to scrutinise their epistemological doubt than others. The individual's feeling that current beliefs are no longer working satisfactorily is, according to Bendixen (2002) and Boyes & Chandler (1992), an essential condition for conceptual change and thus of high educational significance. That Primary School students are already able to apply strategies to question knowledge, and thus actively influence their own conceptual change, is an important finding that became evident during this study.

Many ten-year-old students could not differentiate between the concept of knowing and the concept of learning. Some students believed that learning precedes knowing. This supports the general position of Schommer-Aikins (2002) that epistemological beliefs are closely connected to beliefs of learning.

Nearly all students at this age were able to define knowledge. These definitions encompassed different levels of abstract thought. The students were aware of different strategies and resources available to them whereby they can access knowledge. They believed that knowledge is mainly passed on from generation to generation. Compared with the beliefs of adults (Baxter Magolda 1992, Belenky et al. 1986, King & Kitchner 1994, Schommer 1990, 1994) Primary School students seemed to have a high diversity of beliefs as to where knowledge originated, for example given by God, discovered by trial and error, and constructed by humans. Increasing age might thus be determinate in reducing the number of their beliefs and simplifying them.

Significance of the Research Study

The results of this research study show that the epistemological beliefs of Primary School students have an important influence on their personal knowledge and its acquisition. Thus, deepening the understanding of this influence is exceedingly important so as to better direct the learning process of Primary School students and to enhance conceptual change within them. As these students seem to deal with the epistemological beliefs of those within their environment, it is not only worthwhile to cultivate appropriate, instructional environments that enable students to develop sophisticated epistemological beliefs, but also to simultaneously nurture sophisticated epistemological beliefs in the teachers themselves. Therefore, the consideration of teachers' epistemological beliefs is of high educational significance for teacher learning and development.

References

Baxter Magolda, M. B. (1992). Knowing and reasoning in college: Gender-related patterns in students' intellectual development. San Francisco: Jossey Bass.

Belenky, M., Clinchy, B., Goldberg, N. & Tarule, J. (1986). *Women's ways of knowing: The development of self, voice and mind*. New York: Basic Books.

Bendixen, L. (2002). A process model of epistemological belief change. In Hofer, B. & Pintrich, P. (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 191 – 208). Mahwah: Lawrence Erlbaum Association.

Boys, M. C. & Chandler, M. (1992). Cognitive development, epistemological doubt, and identity formation in adolescence. *Journal of Youth and Adolescence*, 21, 277-303.

Chandler, M., Hallet, D. & Sokol, B. (2002). Competing claims about competing knowledge claims. In Hofer, B. & Pintrich, P. (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 145 – 168). Mahwah: Lawrence Erlbaum Association.

Elder, A. (2002). Characterizing fifth grade students' epistemological beliefs in science. In Hofer, B. & Pintrich, P. (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 347 - 363). Mahwah: Lawrence Erlbaum Association.

Hofer, B. & Pintrich, P. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67, 88 – 140.

Hofer, B. & Pintrich, P. (Eds.). (2002). *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Mahwah: Lawrence Erlbaum Association.

King, P. & Kitschner, K. (1994). Developing reflective judgement: Understanding and promoting intellectual growth and critical thinking in adolescents and adults. San Francisco: Jossey-Bass.

Kuhn, D. & Weinstock, M. (2002). What is epistemological thinking and what does it matter? In Hofer, B. & Pintrich, P. (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 121 - 145). Mahwah: Lawrence Erlbaum Association.

Piaget, J. (1950). *Introduction a l'epistemologie genetique*. Paris: Presses Univ. de France.

Schommer, M. (1990). Effects on beliefs about the nature of knowledge on comprehension. *Journal of Educational Research*, 82, 498 - 504.

Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review*, 6, 293 - 319.

Schommer-Aikins, M. (2002). An evolving theoretical framework for an epistemological belief system. In Hofer, B. & Pintrich, P. (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 103 - 118). Mahwah: Lawrence Erlbaum Association.

Schommer-Aikins, M. Brookhart, S. & Hutter, R. (2000). Understanding middle students' beliefs about knowledge and learning using a multidimensional paradigm. *Journal of Educational Research*, 94, 120-127.

B. Methodological Issues in Studying Conceptual Change

Chair: Lucia Mason, University of Padua, Italy

Discussant: Patricia Alexander, University of Maryland, USA

Transfer of Imagery and Runnability from Analogies to Models

John Clement, University of Massachusetts, Amherst, USA

Objectives

The relationships between schemas, analogy, model construction, and especially imagery and mental simulation, are central to, but still poorly understood in theories of conceptual change in science (Nersessian, 2001; Duit, et al, 2001; Gentner, 1989; Finke, 1990). In particular there is still a significant gap in understanding the role of imagery in learning via analogy. In this paper I will analyze video taped model construction protocols from two case studies of an expert and a student to generate grounded hypotheses concerning: the relationship between "runnable" schemas and imagery during mental simulation; and how assembling a scientific model from simpler runnable analogue schemas can "transfer runnability" to the model.

Method

The database for the first case study comes from professors and advanced graduate students in scientific fields who were recorded while thinking aloud about the problem of whether a wide spring stretches more than a narrow spring. Videotapes were analyzed to identify depictive hand motions and other observations that are potentially relevant to imagery and simulation use (Clement, 2003). I will analyze the role of analogy in the case of a subject who develops an insightful solution to the problem.

The protocol for the second study comes from videotapes of a high school student being tutored in an electricity curriculum that uses analogies to construct models of electric potential (voltage) and charge flow (current). These models were anchored in the student's intuitions about pressure and airflow. The student was given eight hours of interactive tutoring over five days. Care was taken to develop an imageable model by starting from concrete analogue examples of pressure (e.g. a leak in a tire) and by using student-generated drawings with a color-coding scheme for different levels of "electric pressure." This subject was able to map and apply the air pressure and flow analogy to electric potential and current as her tutor helped her build a model for electric circuits.

By using constant comparative methods, both observational and theoretical constructs were developed in order to formulate grounded hypotheses explaining how learning occurred in each subject (Clement, 2000). These hypotheses were criticized and revised over many cycles by asking where they failed to account for transcript segments.

Findings

In the case of the expert, a breakthrough was reached when he discovers a twisting and torsion effect in the spring by examining analogous cases such as a polygonal spring coil and a straight rod being twisted from both ends. As he talks about the latter case he makes twisting motions with his hands. These kinesthetic and other imagery indicators such as spontaneous imagery reports and personal action projections are explained by hypothesizing that he is engaged in a series of imagistic simulations wherein a perceptual motor schema for twisting objects operates on an internal image to produce a mental simulation. Later when he is analyzing the real circular coil of a spring and attempting to locate twisting effects there, he makes very similar twisting motions with his hands. This suggests a transfer of imagery and runnability from the earlier source schema used in the twisting rod case to a target model being constructed for the circular coil, as evidenced by the similar hand motions.

In the case of the student, a tutor used analogies to construct models of electric potential (voltage) and charge flow (current) and she anchored these in the student's intuitions about (perceptual motor schemas for) pressure and air flow. This subject was able to gradually map and apply an air pressure and flow analogy to electric potential and current as her tutor helped her build a model for electric circuits (Clement and Steinberg, 2002). This was again supported by evidence from the subject's spontaneous use of similar depictive hand motions over drawings during the original air analogy and during the instructional circuit examples, indicating that she was using a similar type of imagery in both cases. This suggests the transfer of imagery and runnability from the analogue air pressure conceptions to the electric potential model. These interpretations can explain many aspects of the transcripts.

Conclusions

Case study evidence from both the expert and student indicates that:

- Analogies can be used as starting points to generate important model elements, not just quick solutions to a target problem
- Hand motions and other observations indicate some analogies are "runnable" -- they generate dynamic imagery.
- Similar depictive hand motions in the analogous case and model are evidence of a "transfer of runnability" from the analog conception to the model

And for the student:

- Similar hand motions during the instruction and during a posttest are evidence that the model retained the ability to generate dynamic imagery that was used in a transfer problem

Theoretical and Educational Significance

Some of the theoretical problems that this work addresses are:

- Filling a gap in the literature concerning how to gather evidence from protocols on whether and when subjects are using imagery or dynamic imagery.
- Previous theories of analogy have emphasized the transfer of higher order relationships (modeled as discrete symbol structures) from a base case to a target case whereas the present work focuses on the transfer of schema driven imagistic simulations from a source analog to an explanatory model or mechanism.

Educational implications of the present work include a new awareness of the properties of the models and analogies that we want students to understand, suggesting the need for:

- Specifying flexible runnable models as the goal of instruction. Colloquially, one needs to develop the students' ability to flexibly generate mental movies of scientific situations.
- Finding a way to detect and assess such knowledge. Some candidates are: Drawing, talking, gesturing, and pointing during explanations.
- Using this to monitor progress during instruction
- Preparing analogies and applications for curricula that build runnable models by:
- Finding runnable base cases
- Finding bridging analogies that aid in the transfer of imagery and runnability
- Having students practice running a model by assigning problems that are solvable in that way, as opposed to rote methods

References

Clement, J. (2000) Analysis of clinical interviews: Foundations and model viability. In Lesh, R. and Kelly, A., *Handbook of research methodologies for science and mathematics education* (pp. 341-385). Hillsdale, NJ: Lawrence Erlbaum.

Clement, J. and Steinberg, M. (2002). Step-wise evolution of models of electric circuits: A "learning-aloud" case study. *Journal of the Learning Scien*ces, *11*, 389-452.

Clement J. (2003). Imagistic simulation in scientific model construction. In *Proceedings of the Twenty-Fifth Annual Conference of the Cognitive Science Society*. Mahwah, NJ: Erlbaum.

Duit, R., Roth, W.M., Komorek, M. & Wilbers, J. (2001). Fostering conceptual change by analogies - Between scylla and carybdis. *Learning and Instruction* 11, 283-303

Finke, R. (1990). *Creative imagery: Discoveries and inventions in visualizations*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 199-241). New-York: Cambridge University Press.

Nersessian, N. J. (2001). Maxwell and the method of physical analogy: Model-based reasoning, generic abstraction, and conceptual change. In *Reading Natural Philosophy: Essays in History and Philosophy of Science and Mathematics in Honor of Howard Stein on his 70th Birthday* edited by D. Malamet. LaSalle, IL: Open Court.

Producing and Maintaining the Cognitive Order

Timothy Koschmann*and Alan Zemel, Southern Illinois University, USA

In a now classic report on conceptual change, Roschelle (1992) described the interactions of two students working at a computer, named for the purposes of his account as "Carol" and "Dana." They were recorded working through a series of problems in fundamental mechanics using a program known as the Envisioning Machine. Their task in each of these challenges was to observe the trajectory of a moving ball displayed within a window, the "Observable World," and to reproduce its motion in a second window, the "Newtonian World." The corresponding object shown in the Newtonian World, referred to as "the particle," could be manipulated by adjusting various parameters such as velocity and acceleration vectors and initial position, though they were not labeled as such in the simulation. Acceleration and velocity were represented in the Newtonian World as two linked arrows referred to by the students as "black arrow" and "light arrow," respectively.

Roschelle's analysis focused on several minutes of interaction that occurred during Dana and Carol's second session working with the Envisioning Machine. Using an interactional perspective with roots in Conversation Analysis (CA), Pragmatics, and Social Constructivism, Roschelle undertook to describe how Dana and Carol's interaction could be seen as conceptual change. Unlike traditional CA approaches, Roschelle adopted a view of conceptual change that was not a members' perspective. For Rochelle, "Conceptual change is seen as a process of learning to register deep features of situations … and restructuring systems of physical metaphors" (p. 210). Thus, the interactional work that Dana and Carol enabled conceptual change. In his analysis, Roschelle examined this interaction for how it enabled the interactants to produce "theory-constitutive metaphors" as evidence of conceptual change.

Specifically, Roschelle made the claim that conceptual change occurred because:

- the participants offered an account of the observed, regular, and reproducible effects of their experimental procedures, an account that seemed to more accurately account for the observed phenomenon, and
- the participants' account accorded well with other known accounts of the same phenomenon.

Beyond this however, it could be added that conceptual change occurred because the participants

- used their experience to ongoingly produce an alternative to their initial account of the observable phenomenon, and
- used the emergent alternative account to produce and explain additional "experimental" changes, i.e. changes designed to affect the relationship between velocity and acceleration suggested by and which were in accord with the account being produced.

By our reading, concepts are not mental constructs that people acquire, but are rather methods by which we organize both the world and our understanding of it (Garfinkel, 2002; Heritage, 1984). We would maintain that concepts are part of a cognitive order by which our transparent sense of the world is sustained. We use the expression cognitive order in much the same way that others (e.g., Jayyusi, 1984) have written of the moral order of our social world.

If we may assume that the life-world is organized in moral and cognitive terms, we could say that the moral and cognitive orders stand as glosses for that which sustains our sense of the transparently "normal" in our world. These orders inform and are sustained by the activities, methods and procedures members perform. They are available to inspection through careful analysis of the sequential organization of unfolding interaction.

From time to time our interactions with the phenomenal world call for us to reframe or rethink our understanding of observable, recognizable and reproducible aspects of that world. Reframing is a gloss for situated and sequentially produced actions that lead to the production of accounts of those aspects of the phenomenal world under inspection. In certain circumstances, this reframing might be labeled as conceptual change.

This has profound implications for the study of conceptual change since concepts can be understood as tools and methods for producing and sustaining a cognitive order. Concepts make evident aspects of the reality they are designed to address or describe. The production of a concept can be seen as part of the work of producing a normative sense of the explainable accountable world. By "accountable world" we mean not only the directly-observable material world, but everything that is understood as ordered and orderly. This would extend, therefore, to worlds of belief, worlds of mathematics, worlds of imagination, etc., all of which may be accorded the status of real by some or all members. By recasting concepts and conceptual change in this way, we are laying the groundwork for an entirely new line of inquiry, one that focuses, not on the acquisition or modification of conceptual structures, but rather on the ways in which the cognitive order is produced and maintained in everyday circumstances.

References

Garfinkel, H. (2002). Ethnomethodology's program: Working out Durkheim's aphorism. Lanham, MD: Rowman & Littlefield.

Heritage, J. (1984). *Garfinkel and ethnomethodology*. Cambridge, UK: Polity Press.

Jayyusi, L. (1984). *Categorization and the moral order*. London: Routledge.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences*, 2, 235-276.

Intentional Analysis and the Interpretation of Interview Data

Liza Haglud and Ola Halldén*, Stockholm University, Sweden

In his *The Child´s Conception of the World* Piaget introduced what he called the *clinical interview* or the *clinical method* (Piaget, 1929/1951). In research on conceptual change, reference is often made to this clinical interview with regard to method (Smith, 1991; Mintzes, Trowbridge, Wandersee & Arnaudin, 1991). However, it looks like what is referred to is how to conduct an interview, not to the problem of interpreting what an interviewee is saying. The aim of conducting a clinical interview is to reveal believes held by the interviewee or to expose conceptions or conceptual structures that in a way are supposed to reside within the interviewee. The relationship between what is said and these beliefs and conceptual structures are not much elaborated on in the literature. It looks like that what is said in an interview in one way or another is regarded as mirroring what is going on in the head of the interviewee. Thus, the relationship between utterance and thought seems to be taken for granted.

This matter of fact has been severe criticised from a sociocultural perspective. It is said that verbal utterances are not used to refer to something in the outer world

and they are neither overt expressions of inner thought. Rather, they are to be looked at as cultural tools used to realize discursive practices (Schoultz*,* Säljö & Wyndhamn, 2001).

In this paper we focus on the problem of going from what is actually uttered in, for example an interview, to how to ascribe meaning to what is uttered and, further on, how to utilize this ascribed meaning in drawing inferences about the speaker's mind, i.e. to his or her embraced beliefs in terms of concepts and conceptual structures as is done in research on conceptual change. In doing so, we take our departure in what Piaget (ibid.) said about the interpretation of interview data and elaborate on his considerations.

In his presentation of the clinical method, Piaget proposed a classification for the evaluation of an interviewee's responses. He differentiated between five kinds of answers: *spontaneous convictions, liberated convictions, suggested convictions, answer at random,* and *romancing,* respectively (Piaget 1929/1951 pp 10-18). For example, Piaget described as a "suggested conviction" when the child "makes an effort to reply to the question but either the question is suggestive or the child is simply trying to satisfy the examiner…" (ibid. p, 10). It is notable that it is not the literal meaning of the utterance that Piaget is talking about here. Rather, it is what the child is doing, in this case satisfying the examiner, that is said to characterise this kind of answer (the same goes for romancing and answers at random as well). A spontaneous conviction, on the other hand, seems to be regarded as mirroring a conceptual structure in one way or another.

Thus, it looks like we have two kind of answers to account for: answers by of which the interviewee does something and answers that in one way or another reports about the interviewee's thoughts. This highlights the question of what justifies us to draw immediate conclusions about a speaker's mind out of what s/he is saying.

In order to justify the undertaking of doing inferences about mental structures from what is uttered we propose that we regard all utterances as actions. Thus, when a speaker utters something s/he is trying to *do* something; s/he is trying to convince us of something, s/he is trying to make us realize that s/he knows something, s/he is trying to make us to do something, etc (cf. Austin 1962; Searle, 1969). With references in philosophy (von Wright, 1971 and Davidson, 2001) a model for the interpretation of such actions is presented.

According to Davidson (2001) a necessary prerequisite for interpretation is the *principle of charity* (cf. Wilson 1959, pp. 521-39; Needham, 1995, p. 318). Interpreting according to the principle of charity means that we ascribe to the speaker some sort of *logical consistency* and also that we assume that the speaker responds basically to the same *salient features* of the world as we would do under the same circumstances. The interpretation, then, is constituted by a process of *triangulation between two subjects and an object* (Davidson 2001, pp.119-203), i.e. a negotiation between two subjects fostering almost the same sort of rationality or consistency and being aware of almost the same salient features of the world.

Thus, in order to understand what a person is uttering or doing we ascribe to her or him certain kind of beliefs as well as the perception of the similar salient features in the world as we experience.

Looking at verbal behaviour as actions involves looking at them as situated. To act is to do something intentionally in a specific situation. With reference to von Wright it is claimed that "Behaviour gets its intentional character from being *seen* by the agent himself or by an outside observer in a wider perspective, from being *set* in a context of aims and cognitions" *(*von Wright, 1971, p.115, emphasise in original). With regard to the actor, this context is build up of beliefs about what it takes to do a specific thing as well as beliefs about what is appropriate and possible to do in the situation at hand. These two kinds of conditions are referred to as *competence oriented* and *discourse oriented determinants*, respectively. Thus, the interpretation of interview data, for example, ought to comprises the act of ascribing to the interviewee a conceptual framework as well as beliefs about the interview setting at hand (cf. Halldén & Strömdahl, 2003).

By analysing interview data in this way and by means of the distinctions made, we argue that it is possible to get at fair descriptions of the fact that the subject is participating in a sociocultural web of meanings as well as s/he can act as a relatively autonomous actor relying on established cognitions and cognitive structures. Criteria for the validation of interpretations like these are also discussed.

References

Austin, J, L. (1962). *How to do Things with Words.* Cambridge, Massachusetts: Harvard University Press.

Davidson, D. (2001). *Inquires into Truth and Interpretation*. Oxford: Clarendon Press.

Halldén, O. & Strömdahl, H. (2003). *Alternative frames of reference and intentional analysis of utterances*. Paper presented at the 10th European Conference on Research on Learning and Instruction, Padua, August 26-28, 2003.

Mintzes, J. J, Trowbridge J. E, Wandersee, J. H, &. Arnaudin M, W (1991). Children's Biology: Studies on Conceptual Development in the Life Sciences. In S. M Glynn, R.. H. Yeany & B. K Britton (Eds), *The Psychology of Learning Science.* 179-204. Hillsdale, New Jersey: Erbaum Associates.

Needham, P. (1995). *Law & Order. Issues in the Philosophy of Science*. Department of Philosophy. Stockholm University, Stockholm.

Piaget, J. (1929/1951). *The Childs Conception of the World*. Maryland: Littlefield Adams Quality Paperbacks..

Schoultz. J, Säljö, R & Wyndhamn (2001), Heavenly Talk: Discourse, Artifacts, and Children's Understanding of Elementary Astronomy. *Human Development 2001;44: 103-118.*

Searl, J. R., (1969). *Speech Acts*. Cambridge: Cambridge University Press.

Smith, E. L (1991). A Conceptual Change Model of Learning Science43-64. Lawrence . In S. M Glynn, R.. H. Yeany & B. K Britton (Eds), *The Psychology of Learning Science*.. Hillsdale, New Jersey: Erbaum Associates.

von Wright, G.H. (1971). *Explanation and understanding*. London: Routledge and Kegan Paul.

Wilson. N. (1959). Substances without substrata, *Review of Metaphysics,* 12, pp. 521-539.

Do Crucial Experiments Produce Conceptual Change? Theoretical and Educational Implications of Some Cases from the History of Science

Marcelo Leonardo Levinas, Universidad de Buenos Aires, Argentina, and Mario Carretero*, Universidad Autónoma de Madrid, Spain

As it is well known, present theories of conceptual change (Schnotz, Vosniadou and Carretero, 1999; Limon and Mason, 2002) are partly based on ideas stemming from historical and philosophical anylisis of science (i.e. Khun and Lakatos ideas on paradigms and research programs changes). Nevertheless, how ideas from history o science can be applied to conceptual change theory and to its instructional implications is still under debate.

Thus, this paper will present some theoretical anaysis based on the role played by crucial experiments on both conceptual change process and science teaching. According to Lakatos (1971), crucial experiments were never considered really crucial when they were performed by the first time. THEY were considered crucial a posteriori, when they were interpreted according to a new theory which was already accepted. In the case of science teaching, when crucial experiments are usually presented at the classrooms, they do not play an efficient role producing conceptual change. This is to say, they do not produce an authentic conceptual change because they do not contribute to refute old ideas and to incorporate new ones. On the contrary, crucial experiments are usually accepted by students as a part of the teachers' authority. We think that in order to reconsider the role of crucial experiments on both conceptual change and science teaching is necessary to take into account the role played by auxiliary hipothesis in the process of testing the fundamental part of any scientific theory. This is to say, students could be able to refute old theory only if they understand the content of those hypothesis. Thus, this paper will insist on the importance of an explicit role of auxiliary hipothesis on the students minds because they could really change the fundamental meaning of any scientific theory. We think if students are not taught to make an explicit use of those hypothesis, conceptual CHANGE will not take place.

In our opinion, ideas developed in this paper could play a role explaining data obtained in previous research (Hammer, 2000; and Elby, 2001, in Physics; Zelik and Bisard, 2000; and Prather et al., 2002 in Astronomy and Cosmology, and Smith et al., 2003 in Mathematics), which showed how even well informed and science instructed subjects do not change their misconceptions.

Some concrete examples will be analysed. All of them are usually included in secondary school curriculum in many countries. They belong to Physics and Astronomy and they present basic knowledge in relation to Earth movement and shape, and also in relation to its position in the universe. More concretely, we will ANALYSE how crucial experiments could or not contribute to conceptual change in relation to the teaching of the following theories and problems, depending on the explicit use students could do of the role of auxiliary hypothesis:

a) Constant light speed, using as auxiliary hypothesis the Earth movement;

b) Universe expansion, establishing the presuposition that Earth is not the centre of universe;

c) The Earth is round, using as auxiliary hypothesis the light's straight spread.

In the case of these three problems, we will compare the way they are usually presented in many textbooks and the way they could be taught according to our analysis. Logical and instructional analysis of these two ways will be presented as well

Finally, educational implications of histoy of science in relation to their possibilities of producing conceptual change will be presented (Levinas, 1998). In our opinion, history of science examples are usually presented in the classrooms in such a way that they simply reproduce crucial experiments without using their possible contribution to authentic conceptual change processes. In this paper, this matter will be fully addressed and new and more creative uses of history of science in the teaching of science will be presented. In relation to this issue, specific examples concerning new theories presentation and the selection of learning problems and instructional activities will be presented as well.

References

Elby A. (2001), Helping physics students learn how to learn, *American Journal of Physics PER. Suppl*. 69, S1, S54-S64.

Hammer D. (2000), Student resources for learning introductory physics, *American Journal of Physics PER Suppl*. 68, 7, S52-S59.

Hurtado de Mendoza D. y Drewes A. (2003), *Tradiciones y rupturas. La historia de la ciencia en la enseñanza*, Buenos Aires, Baudino Ediciones. y Universidad Nacional de San Martín.

Kim E. and Park J. (2002), Students do not overcome conceptual difficulties after solving 1000 traditional problems, *American Journal of Physics* 70, 7, 759-765.

Lakatos I. (1971), History of Science and Its Rational Reconstructions, in *Boston Studies in the Philosophy of Science, vol. VIII*, pp. 92-182.

Levinas, M. L. (1998), *Conflictos del Conocimiento y Dilemas de la Educación*, (Knowledge conflicts and Education Dilemmas) Buenos Aires, Aique Grupo Editor.

Limon, M. & Mason, L. (eds.) (2002) *Conceptual Change*.

Prather E., Slater T. and Offendahl E. (2002), Hints of a Fundamental Misconception in Cosmology, Astronomy Education Review, 1(2), 28.

Smith N., Lambdin D., Lindquist M. and Reys R. (2003). *Teaching Elementary Mathematics: A Resource for Field Experience*, 2nd edition, New York, John Wiley & Sons Inc.

Schnotz, W., Vosniadou, S. & Carretero, M. (eds.) *New perspectives on conceptual change*. Amsterdam: Elsevier.

Zeilik, M. And Bisard W. (2000), *Conceptual Change in Introductory-Level Astronomy Courses*, Journal of College Science Teachers, 29 (4), 229.

Is conceptual change necessary for experts to change a learned skill error? The example of expert athletes in fin swimming with prior knowledge in the swimming style of butterfy

Maria Koulianou, Stella Vosniadou, University of Athens, Greece

The present study examines the relation between the motor learning of the Undulatory movement in Fin Swimming and the previous knowledge in the swimming style of butterfly within the theoretical framework of conceptual change. The basic question is whether the development of a new sport behavior presupposes the reorganization of prior motor experiences similar to nonsport settings as physics, mathematics and astronomy (Vosniadou & Brewer, 1992, 1994). The basic theoretical framework is based on work in cognitive developmental psychology (Vosniadou, & Brewer, 1992) and in cognitive science (Chi, Feltovich & Glaser, 1981, Carey, 1994), which shows that there is considerable conceptual reorganization of prior knowledge required in the process of development or the acquisition of expertise in a domain. The central assumption of this study is that the prior knowledge of the athletes in the swimming style of "butterfly" makes the empirical performance of the new fin swimming style difficult. The hypothesis was tested both at theoretical and practical level. At the first part the athletes (n=12) of the National Team had to perform some exercises (25m immersion, 50m surface, etc.) during their training. The coaches of the National Team observed and marked athletes' performance. At the second part the same athletes had to complete a questionnaire with 30 questions. After the questionnaire the athletes of the National Fin Swimming team gave an individual interview.

A qualitative analysis of the results shows the following:

Prior knowledge of butterfly swimming style inhibits the acquisition of the correct Undulatory movement in Fin swimming.

The athletes seem to construct a mental model to compromise the distinction between butterfly and fin swimming style. This dynamic structure is formed of and constrained by underlying structure of butterfly knowledge.

Practice although is valuable and necessary for learning a new skill seems to be unsuccessful in the face of an established technique error (Lyndon, 2000, Hanin et all, 2002).

Conceptual change seems to be necessary for the correction of the learned technique errors and the establishment of the new motor skill.

References

Hanin Y., Jouste P., Korjus T., Baxter P (2002). Rapid Technique Correction Using Old Way / New Way: Two Case Studies with Olympic Athletes. *The Sport Psychologist*, 16, 79-99.

Carey S., and Spelke E., (1994). Domain-specific knowledge and conceptual change. *In Mapping the Mind*, L. A Hirschfeld and S. A. Gelman (Eds.). New York, NY: Cambridge University Press.

Chi M. & Feltovitch P. & Glaser R., (1981). Categorization and Representation of Physics Problems by Experts and Novices. *Cognitive Science* 5: 121-152.

Koulianou Maria. (2000). *Cognitive Science and Sport Psychology: Experts and Novices in Fin Swimming*. Unpublished Master Thesis. Athens: Graduate Programme in Basic and Applied Cognitive Science, Department of History and Philosophy of Science, University of Athens.

Lyndon, E. H. (2000). *Conceptual mediation: A new theory and new method of conceptual change*. Australia: University of Adelaide. Unpublished doctoral dissertation.

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

Vosniadou, S., Brewer F.W. (1994). Mental models of the day /Night Cycle. *Cognitive Science 18*, 123-83.

Vosniadou S., (2002). *Mental Models in Conceptual Development.* In Model Based Reasoning: Science, Technology and Values, L. Magnani & N. J. Nersessian (Eds.), New York: Klumer Academic/ Plenum Publishers.

C. Conceptual Change in Environmental Education

Chair: Lia Halkia, University of Athens, Greece

Discussant: Silvia Caravita, Instituto di Scienze e Technologie della Cognizione, CNR, Rome, Italy

Concept Formation in Environmental Education

Karolina Österlind, Stockholm University, Sweden

The paper presents result from a study of pupils' (aged 14) work on two environmental issues studied in school, one concerning the depletion of the ozone layer and the other the enhanced greenhouse effect. The paper addresses the issue of concept formation in environmental education and, on a more general level, the question of what are the conditions for conceptual change.

In research on conceptual change it has been acknowledged that students' conceptions of individual phenomenon, are part of conceptual systems (Caravita & Halldén, 1994; Tiberghien, 1994; Vosniadou, 1994). Caravita & Halldén (1994) differentiate between different levels within such systems: theoretical, conceptual and empirical level (se also Halldén, 1988, 1999; Halldén, Petersson, Scheja, Ehrlén, Haglund, Österlind & Stenlund, 2002). Students' alternative conceptions of various phenomena are viewed as a result of the students interpreting these phenomena within conceptual contexts that are different from the more scientific frameworks that are of relevance in instruction. That means that the students are observing other aspects of the phenomena. The difficulties that the students encounter in learning science concepts are looked upon as problems of differentiating between contexts for interpretation (Caravita & Halldén, a.a.).

The study presented in this paper examines pupils' work in an instruction that is organised thematically and which uses a discovery method of teaching. Given the view on pupils' difficulties as problems of differentiating between contexts, it is assumed that it is of interest to examine pupils' concept formation in this kind of instructional design. The thematic organisation implies that concepts belonging to theoretical contexts are situated in practical contexts. Thus, it is a mixture of different contexts in instruction, i.e. theoretical and practical contexts. The use of a discovery method of learning implies that pupils must identify a relevant context for the information without much help from their teachers.

The study was carried out in a class that for a period of six weeks was working on a segment concerned with environmental issues. The pupils worked in small groups of 4-5 pupils each and the analysis is based on the work of one of the groups. Data consists of tape-recorded conversations among the pupils in the group and between the pupils and their teachers, and the pupils' written material. The paper presents result from the work of two pupils, Julia and Tom.

The result shows that the pupils have difficulties in learning the environmental issues under study. Julia, for example, confuses the two issues. Further it is assumed that certain domain-specific knowledge that are brought to the fore in the pupils' work on the issues, would have facilitated their understanding of the issues. This knowledge is for example explanations of the phenomena such as photosynthesis and catalyst. However, the pupils have difficulties in finding the meaning of the individual concept that is relevant in the explanation of the environmental issue under study.

One example of this is Tom's work on the concept of catalyst. Tom is working on the problem of ozone layer depletion and is then requested by the teacher to find out what catalyst means. Catalyst in this context refers to a chemical substance that accelerates the destruction of ozone. Tom looks up the word in a reference book, but here he finds an explanation of catalyst as a catalyst converter that is used in cars. However, Tom is not able differentiate between the different meanings of the concept of catalyst, i.e. catalyst as a chemical substance and catalyst as a catalyst converter. And so he writes a text that explains catalyst as a catalyst converter.

Another example is Julia's interpretation of the concept of photosynthesis. In the course of her work on enhanced green house effect Julia encounters the concept of photosynthesis in a text. Photosynthesis is here described as a process that has relevance for the concentration of carbon dioxide in the atmosphere since plants absorb carbon dioxide in this process. In order to construct an understanding of photosynthesis and, in the long run, of the enhanced greenhouse effect, Julia looks up the term photosynthesis in a reference book. However, in this book she finds a more general theoretical description of the concept of photosynthesis, which describes also other aspects of photosynthesis, like the transformation of energy and the production of oxygen. These aspects are not relevant in the explanation of enhanced green house effect. The notable thing is that Julia does not differentiate between the different aspects, and so she does not discern what aspect of photosynthesis is of relevance in the explanation of the enhanced greenhouse effect. In her text on photosynthesis, she describes the transformation of energy in photosynthesis, instead of the absorption of carbon dioxide.

Thus, the result shows that the pupils have difficulties in finding the meaning of the individual concept that is of relevance in the environmental issue under study. The concepts figure in different conceptual contexts, i.e. the environmental issues and the theoretical contexts. In these different contexts the concepts take on different meanings. It is for example only one aspect of photosynthesis as described in a theoretical context, which is of relevance in a practical context, the environmental issue. The difficulty the students encounter in understanding the scientific concepts consists of orienting themselves in and between these conceptual contexts. The pupils' difficulty is looked upon as a problem of contextualisation (Halldén, 1999).

The result provides ground for questioning the view on cognitive conflict as instrumental in promoting conceptual change (Posner et al. 1982). The pupils do not seem to experience any conflict between different explanations in spite of the fact that the explanations of the individual phenomenon that they find in texts, are not of relevance in the environmental issues under study. What is striking in this material is, on the contrary, the pupils' tendency to incorporate, or in Piagetian terms: to assimilate (Piaget, 1935), the explanations they find with the explanation they already possess.

References:

Caravita, S. & Halldén, O. (1994). Re-fraiming the Problem of Conceptual change. *Learning and instruction, 4,* 89-111.

Halldén, O. (1988). Alternative Frameworks and the Concept of Task. Cognitive Constraints in Pupils' Interpretations of Teachers Assignments. *Scandinavian Journal of Educational Research, 32,* 123-140.

Halldén, O. (1999). Conceptual change and contextualization. In Schnotz, W., Vosniadou, S. & Carretero, M. (Eds), *Conceptual change.* Amsterdam: Elsevier.

Halldén, O., Petersson, G., Scheja, M., Ehrlén, K., Haglund, L., Österlind, K. & Stenlund, A (2002). Situating the question of conceptual change. In M. Limon & L. Mason (Eds.), *Reconsidering Conceptual Change: Issues in Theory and Practice.* Dordrecht: Kluwer Academic Publishers.

Piaget, J. (1935/1970). The origin of intelligence in the child. London: RKP.

Posner, G.J., Strike, K.A., Hewson, P.W. & Gertzog, W.A. (1982) Acommodation of a Scientific Conception: Toward a Theory of Conceptual Change, *Science Education, 66 (2),* 211-227.

Tiberghien, A. (1994) Modeling as a basis for analyzing teaching –learning situations. *Learning and Instruction, 4,* 71-87.

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

Conceptual Change: From Research to Instructive Practice. For a Timely Dealing with Students' 'Lamarckian' Views

Lucia Prinou*, Lia Halkia and Constantine Skordoulis, University of Athens, Greece

Introduction

The Greek educational system appears even today, particularly conservative with the subject of teaching evolution. Evolution, as a complete unit is at the end of 9th grade biology textbook, and the majority of teachers do not teach it. But even though it is taught, teachers are not informed on the results of cognitive studies, and so they do not know that they need to take into account their students' ideas, and use them to plan their teaching. Evolution is not taught in the 12th grade either. In 12th grade the relevant chapter is removed from the subject matter of the course and so far, it has been exempted from the teaching of biology. All this, results in students graduating from a Greek school, while having been taught very little and thus being deprived of basic knowledge on evolution. Specifically they use the «Lamarckian» model, "the most pervasive among students" (Jensen and Finley 1995) to explain biological change.

Theoretical background

Lamarckian» views are considered to be the explanations of biological change as effects of the environment, resulting in changes in individuals and inheritance of these acquired traits but also including ideas about changes in DNA due to environmental factors (Jimenez-Aleixandre1996). According to Bishop and Anderson (1990), students fail to make a distinction between the appearances of traits in a population and their survival over time. They think that there is a single process in which characteristics of the species gradually change and believe that the environment causes traits to change over time. Comprehensive didactic interventions are reported in bibliography, focused on "Lamarckian" views (Jensen and Finley 1995, Jimenez-Aleixandre 1992, 1996, Stern 2002 etc.), in genetics-evolution (Banet and Ayuso 2003), etc.

As far as the theory for conceptual change is concerned, a distinction is made according to Vosniadou et *al*. (2001) between the views of science learning presented by Posner et al. (1982), which focuses on the incompatibility between two distinct and equally well-organized explanatory systems, one of which will need to be abandoned in favor of the other and the "different in fundamental ways" based on the results of cognitive studies.

Vosniadou *et al*., (2001) suggest that conceptual change is a slow revision of an initial conceptual system through the gradual incorporation of elements of the currently accepted scientific explanations.

Aims

In the particular research, an effort is made, through instructive interventions, in order to pave the way for teaching evolution. It is focused on the challenge of conceptual change of the 9th grade students' "Lamarckian" conceptions. The research question was whether the consolidating concepts on genetics, can be useful for a timely dismantling of the students' Lamarckian" conceptions and can lead to the notion of natural selection. Our interventions were sought much earlier than teaching the unit of evolution, without the invocation of names or terms (adaptation, natural selection, Lamarck, Darwin etc.), left for another time of the instruction.

Methodology

a) Greek biology curricula and textbooks were explored, with criteria to localize points - in their structure and the way of analysis of concepts - in order to find out whether they face or contribute to the makeup of students' synthetic models.

b) Conduct of research in three phases:

1st: Investigating 9th grade students' synthetic models, through pre - tests which asked them to interpret instances of biological change. Almost 60% of students held Lamarckian views (the rest were tautological or uncodeable answers). Their views were similar to those in bibliography and concerned the way in which the environment is believed to exert its influence, including the need, use or disuse, and adaptation (Bishop and Anderson1990, Brumby, 1979, 1984, Clough and Wood - Robinson 1985, Hallden 1988 etc.).

2nd: There followed *short-term, exploratory* interventions, based on the pre-tests findings. The instructive interventions were focused basically on:

- The role of variation within a population, (a concept ignored by students) - The random mutations, as a source of variation. This is a very important key-point for conceptual change. In that phase, interventions tried to make students capable of comprehending that the environment does not dictate these mutations to DNA, required by the organisms … Moreover that individuals with suitable traits, will contribute more offspring to the next generation and … thus populations change through the changing proportion of individuals.

After the interventions, there followed a discussion on particular examples, among students in groups and with the whole class.

3rd: *Three weeks later*, questionnaires were handed out to students, which called on them to interpret other instances of biological change.

Three 9th grade classes (24-25 students each) of a public school participated in the research, in hours granted by teachers of the school.

Findings - Conclusions

a. Greek biology curricula and textbooks do not take into consideration students' synthetic models.

The references to the concept of Adaptation/s in lower, than 9th grade, grades, leaves space to alternative explanatory models to grow, at a time when the exact interpretation of Adaptation is not possible.

b. Conceptual change appears to have taken place in principle. After the interventions, 30% of students, abandoned "Lamarckian" views and interpreted the instances of the questionnaire, with the notion of natural selection. This shows that when *prerequisite concepts* are built in time, and with the teachers' conscience of their future utilization, *they* have the dynamics to constitute conceptual structures, which can replace students' explanatory models, like "Lamarckians". Moreover, it may not be necessary, to wait for "*a*" chapter of evolution, in order to introduce all the relevant concepts. We can begin introducing them, in various previous phases of teaching biology.

c. In our research, an equally well-organized explanatory system, *the "Lamarckian" in this case*, is abandoned in favor of the other. However during this process, students were helped to become aware of their existing beliefs and presuppositions, and to create larger theoretical constructions that have greater explanatory adequacy, as Vosniadou *et al*. (2001), have described.

References

Banet, E. & Ayuso, G.E. (2003), Teaching of biological inheritance and evolution of living beings in secondary school *International Journal of Science Education* 25(3), 373-407.

Bishop, B.A., & Anderson, C.W. (1990), Students conceptions of natural selection and its role in evolution, *Journal of Research in Science Teaching, 27*(5), 415-427.

Brumby, M (1979), Problems in learning the concept of natural selection, *Journal of Biological Education*, 13,119-122.

Brumby, M. N. (1984), Misconceptions about the concept of natural selection by medical biology students, *Science Education*, 68, 493-503.

Clough, E.E., & Wood-Robinson, C. (1985). How secondary students interpret instances of biological adaptation, *Journal of Biological Education*, 19, 125-130.

Hallden, O. (1988), The evolution of species: Pupils' perspectives and school perspectives, *International Journal of Science Education*, 10, 541-552.

Jensen M.S. & Finley F.N. (1995) Teaching evolution using historical arguments in a conceptual change strategy, *Science Education,* 79, (2), 147-166.

Stern, L. (2002) Challenging middle-school students' ideas about the inheritance of acquired traits using a history of science case study and guided discussions. *Third European Symposium on Conceptual Change*, Proceedings, 94- 97.

Jimenez-Aleixandre, M. P. (1992), Thinking about theories or thinking with theories: A classroom study with natural selection, *International Journal of Science Education, 14*, 51-61.

Jimenez-Aleixandre, M.P. (1996). Darwinian and Lamarckian models used by students and their representations. In Fisher, K.M. & Kibby, M. (Eds.), *Knowledge acquisition, organization and use in biology* (pp 65–77). New York: Springer Verlag.

Vosniadou S., Ioannides C., Dimitrakopoulou A., Papademetriou E. (2001) Designing learning environments to promote conceptual change in science, *Learning and Instruction* 11,381-419.

Effects of Conceptual Change Approach on Ninth Grade Students' Ecology Achievement: Attitudes towards Biology and Environment

Gülcan Çetin*, Hamide Ertepinar and Ömer Geban, Middle East Technical University, Turkey

This study examined the effect of conceptual change texts accompanied by demonstrations within small groups on students' understanding of ecology, and attitudes towards biology and environment. Ecology is one of the central but abstract concepts in biology. Researchers have found and explored students' common misconceptions about ecological concepts. For instance, Adeyini (1985) stressed that the students had common misconceptions on food chain, energy flow, energy pyramid, and carbon cycle. Gallegos, Jerezano, and Flores (1994) examined the students' misconceptions about food chain. Also, Çetin (1998) reported that eighth grade students had difficulty in explaining the origin of flow of energy in a food chain and some students considered the producer or consumer responsible for the decay in an ecosystem.

There is a need for effective science teaching and learning in our schools in order to eliminate misconceptions and improve students' understanding levels in science courses. However, traditional instruction cannot remove easily the students' common biological misconceptions. Several effective strategies like conceptual change strategies can be used to eliminate students' common misconceptions and increasing students' understandings of science concepts. One of the more effective strategies for science classes is conceptual change approach such as concept maps (Wallace and Mintzes, 1990), conceptual change texts (Sharon and Chambers, 1997), and cooperative learning strategy (Lazarowitz et al., 1994), etc. For example, Özkan (2001) found that conceptual change text oriented instruction showed a statistically significant effect on seventh grade students' ecology achievement.

A quasi-experimental design was employed in the study. 82 students in four classes from a high school were involved in the study. As the classes were formed beforehand, sampling was a convenience sampling. Two classes were assigned as control group and two classes were assigned as experimental group. Both teachers and their students were assigned to one of the treatment conditions beforehand. In the control group, traditionally designed methods were used to teach ecology using by direct lecturing, questioning, and giving everyday life examples. In the experimental group, conceptual change approaches were used to teach ecology using by conceptual change texts supported with demonstrations in small groups in two hours for five weeks. While two control classes used the same curriculum materials (same textbook), two experimental classes used conceptual change texts, worksheets, and demonstration materials. The teachers were trained about how conceptual change approaches would be implemented in their classes.

The students' ecology achievement was measured before and after the treatment with the TEC. Moreover, the Attitude Scale towards Biology (ASB) and Attitude

Scale towards Environment (ASE) measured the students' attitudes towards biology and environment before and after treatment. Test of Logical Thinking (TOLT) was also given to the students as a pre-test.

The students in the experimental group were delivered conceptual change text before each ecology lessons. After the teacher had read the misconceptions given in the conceptual change text, the students were given worksheets that were involved some questions related to the demonstrations. Then, the students were presented with some demonstrations of energy pyramid model; posters of carbon, water, oxygen, carbon dioxide, phosphorus, and nitrogen cycles; plants and dead animals. Later, the students were asked to discuss the questions in small groups. Questions were related to demonstrations. Finally, the teacher performed a whole class discussion about the ecology, and, if it was necessary to facilitate to understanding to ecology topics, she also explained the ecology topics.

The MANCOVA was computed for variables of both the experimental and the control group. After the data obtained from the TEC, ASB, and ASE before and after treatment, the data were computed by the MANCOVA for variables of the experimental and the control groups. In the study, the treatment and gender were independent variables; post-TEC, post-ASB, and post-ASE were dependent variables, and pre-TEC, pre-ASB, pre-ASE, ABG, and TOLT were assigned as covariates. Furthermore, content analysis of the results of the Test of Ecological Concepts was performed.

The summary of MANCOVA indicated $F(1, 73)=10.912$ and $p=.001$. This showed that there was a significant difference in the means of the post-TEC between the CCTI and the TI when the effects of the covariates have been controlled. The CCTI was more effective in improving students' post-TEC scores than the traditional instruction. Students were taught using the conceptual change oriented instruction had higher ecology achievement scores than the students were taught using the traditional instruction. On the other hand, it was found that there was no significant main effect of gender difference on the students' ecology achievement ($F(1, 73)=.206$, $p=.651$). That is, there was no significant difference in the means of the post-TEC between males and females when the effects of the covariates have been controlled. Gender difference was not effective in improving students' post-TEC scores. Finally, it was found that there was no significant main difference of interaction between the treatment (the CCTI over the TI) and gender difference on the post-TEC ($F(1, 73)=1.094$, $p=.299$). In short, the interaction between the treatment and gender was not effective in improving students' post-TEC (Çetin, 2003).

The following conclusions can be drawn from the results of the study: The CCTI was effective in eliminating students' common misconceptions about ecological concepts and it caused statistically significant increase in the experimental group students' understanding and achievement of ecological concepts. However, it did not improve students' attitudes towards biology and environment. Additionally,

gender differences, and the interaction between the treatment and gender difference did not show a significant effect on the students' understanding and achievement of ecological concepts, attitudes towards biology, and attitudes towards environment. In short, it was found that if a science course was taught by conceptual change texts oriented instruction supported with some demonstrations and students' discussions in small groups in this study, this course yielded more successful achievement results than the traditional instruction.

We can recommend that teachers and curriculum developers should also be informed about importance and usage of conceptual change approaches in teaching science concepts. For example, using conceptual change texts would provide students to realize students' common misconceptions on ecology and the remediation of these misconceptions. Since the conceptual change texts including worksheets used in this current study were clear and easy to follow by the teachers and the students, they can also be used for science and biology classrooms. Also it would be better to see whether studies in other countries would produce similar in order to increase the reliability of test results of the study.

References

Adeniyi, E.O. (1985). Misconceptions of selected ecological concepts held by some Nigerian students. *Journal of Biological Education*, 19(4), 311-316.

Çetin, G. (1998). A comparison of some English and Turkish students' understanding of selected ecological concepts. Unpublished Master Thesis, University of Leeds, Leeds.

Çetin, G. (2003). *The effect of conceptual change instruction on understanding of ecology concepts*. Unpublished Ph.D. Thesis, Middle East Technical University, Ankara.

Gallegos, L., Jerezano, M. E., & Flores, F. (1994). Preconceptions and relations used by students in the construction of food chains. *Journal of Research in Science Teaching*, 31, 259-272.

Lazarowitz, R., Hertz-Lazarowitz, R., & Baird, J. H. (1994). Learning science in a cooperative setting: Academic achievement and affective outcomes. *Journal of Research in Science Teaching*, 31, 1121-1131.

Özkan, Ö. (2001). Remediation of seventh grade students' misconceptions related to ecological concepts through conceptual change approach. Unpublished Master Thesis, The Middle East Technical University, Ankara.

Sharon, K., & Chambers, T.A. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching*. 34(2), 107-123.

Wallace, J. D., & Mintzes, J. J. (1990). The concept map as a research tool: Exploring conceptual change in biology. *Journal of Research in Science Teaching*, 27(10), 1033-1052.

Webb, P., & Boltt, G. (1990). The food chain to food web: A natural progression? Journal of Biological Education, 24(3), 187-197.

Pupils' Conceptions as a Basis for Teaching Global Warming

Tiina Nevanpää, University of Jyväskylä, Finland

Students' understanding of different scientific content has been in the focus of research in the field of learning and instruction during last decades. It is now evident that students' usually have pre-instructional ideas and conceptions that affect their active learning process. However, there has been critizism that contribution of these research findings to planning the content of teaching as well as changing the classroom practices has been limited. The aim of this paper is to examine Finnish pupils' pre-instructional conceptions about global warming and consider their role in the learning process in the light of analysis of content structure. Global warming was selected as subject of the study since it is one of the most influential and wide-ranging environmental problem which have substantial effects on ecological equilibrium and to modern societies. Furthermore, previous studies have shown that pupils' ideas differ from scientific view also after learning the subject at school. Thus global warming challenges not only science teaching but also research on learning and instruction.

The model of educational reconstruction (Duit et al. 1997) was used as a frame of the study. The model consists of three components: analysis of content structure, empirical investigations and construction on instruction. In this paper results of content analysis and empirical study of pupils' conceptions are introduced.

In the model of educational reconstruction pupils' understanding of the basic ideas of the scientific phenomena to be studied are investigated empirically. In this study a questionnaire with free-response items was designed and administered to study pupils' pre-instructional conceptions about global warming. In order to stimulate pupils' thinking, a short text describing Earth's measured mean temperatures and the perceived rise in temperatures during last decades was attached. The pupil was asked to explain what the described phenomenon is and what caused it. The pupil was also asked to explain the ways to prevent the phenomena.

The empirical data consisted of written answers of 457 7th graders. Responses were analysed qualitatively by using a phenomenographic approach in a practical manner (Marton, 1994). As a result of analysis 7 distinct categories describing pupils' understanding of global warming emerged. In 2 of them global warming was causally connected to ozone depletion. To summarise, pupils' understanding of global warming was insufficient as expected since they haven't got any formal teaching about the content. However, pupils seem to recognise concepts connected to global warming. Nevertheless the connections between concepts are different from scientific view. It seems that pupils do not understand global warming as natural phenomena that is increased by human actions. The causes of global

warming are not differentiated in pupils' cognitive structures as they mentioned wide-range human actions as a cause to the phenomena. Pupils mentioned only some distinct causes of global warming (e.g. melting of polar glaciers) without reference to wide-ranging ecological or societal consequences. Pupils seldom described the processes of global warming and their few descriptions were scientifically incorrect (e.g. decreasing atmosphere is the cause of warming). It seems, that the pupils' cognitive structures consist of separate facts in a sense that a conceptual frame i.e. scientific grounding is missing. This may be the reason for incorrect connection of concepts.

The purpose of analysing scientific content structure is to reconstruct contents structures in a way that the elementary features are emphasized. In the analysis the perspective is widened to include not only the scientific view of the content but also educational standpoint. In this way the key elements of global warming were detected from the perspective of science education.

Global warming is scientifically complex phenomenon with close connection modern society. In order to understand global warming pupils need to understand abstract concepts and to connect them scientifically meaningful way. Furthermore, speculations and wild cards in scientific view make the phenomenon even more difficult to understand. Thus the explanation of global warming that is suitable for education is simplified view of the phenomena including only the most leading concepts. Explanation is based on understanding the interplay between radiation and atmosphere in the process of regulation of Earths' temperature. It is crucial to understand that human actions have altered the composition of the atmosphere and thus altered the natural balance of radiation. The causes of global warming must be clarified in order to distinct it from other environmental problems. Attention should be paid to help pupils to form comprehensive understanding of both scientific and societal consequences of global warming.

Comparison of pupils' conceptions and elements in the educational explanation reveals that pupils need sufficient elementary knowledge of science (e.g. physics, ecology) in order to form scientifically correct and a coherent conception of global warming. Lack of this conceptual frame may be one reason for constructing conceptions that differ from scientific view. Development of conceptual understanding is endorsed by limiting the number of concepts in the beginning of the learning process. After understanding the key elements of global warming pupils can widen and deepen their understanding of the phenomenon. To fully understand global warming and the debate over it pupils also need to understand the nature of scientific knowledge.

Results of this paper can be used to develop science teaching and learning since it points out key elements in teaching global warming. Theoretically paper raises interesting assumptions about the meaning of conceptual frame in the learning process. It also gives raise to speculations of development of conceptual understanding since it seems that at least Finnish pupils do not have model- or theory-based pre-instructional conceptions about global warming.

References

Duit, R., Komorek, M. & Wilbers, J. 1997 Studies on educational reconstruction of chaos theory. *Research in Science Education*, 27(3), 339-357.

Marton, F. 1994 Phenomenography. In Husén, T. & Postlethwaite, T.N. (eds.) *The international ensyclopedia of education* (2nd edition) Oxford: Pergamon. 4424-4429.

Changes in High School Students' Conceptions about Evolution by Natural Selection: A Case Study

Luli Stern* and Nirit Di Nur, Technion - IIT, Israel

Evolution of living organisms is a central scientific theory that explains and synthesizes observations in many different areas of biology. As Dobzhansky, one of the framers of the Neo-Darwinian evolutionary synthesis wrote, "Nothing in biology makes sense, except in the light of evolution" (1973). The teaching of evolution has been widely advocated by many scientists and science educators' world wide. Research on student learning, however, repeatedly indicates that it is one of the most difficult theories to accept (Bishop & Anderson, 1990; Brumpy, 1984; Clough & Wood-Robinson 1985; Damastes et al, 1995). Studies show that high school and college students, even after relevant instruction, have difficulties understanding the notion of natural selection. It relies upon the understanding of other ideas and goes against intuition and everyday life experience. For example, in everyday life, individuals adapt deliberately to changes in their environment. Consequently, students explain gradual changes in populations in terms of deliberate change of individuals rather than inadvertent change in the proportion of individuals carrying advantageous traits in a population. Likewise, students may sometimes see that traits such as smoking or bodybuilding "run" in some families and intuit incorrectly that learned traits are inherited.

The study presented in this paper was carried out on *Science for All* Israeli students and attempted to challenge and monitor students' naïve ideas related to natural selection. *Science for All* is a subject that is being offered at the high school level in Israel as an alternative to biology, chemistry, or physics courses. The intention of this program is to expose all students to scientific principles in order to help them become literate adults in an increasingly complex world. Whereas natural selection is a desired learning outcome in this curriculum framework, curricular materials that attempt to address the naïve ideas documented in the literature and are aimed at this particular student population have not yet developed in Israel.

The objective of this study was to document and describe tenth grade students' ideas regarding the concept of natural selection throughout the introduction of a newly developed conceptual change-based unit. To accomplish this goal, the ideas of all the students in the classroom were characterized before and after the instruction. In addition, the ideas of four students were documented in detail throughout the teaching process. This empirical study attempted to provide insight into students' thinking and the effectiveness of curricular strategies related to evolution.

Methodology and context of the study

Sources of data included written diagnostic questionnaires, semi-structured interviews, and classroom observations. The curriculum used in this study was part of a more comprehensive module that is currently being developed at the Technion. The results of a previous study in which an earlier version of the unit was tried with ninth grade students were encouraging; as the unit helped some of these ninth graders understand the basic concept of natural selection.

Instructional strategies emphasized in the unit included identifying and addressing students' ideas, engaging students with multiple, varied phenomena, and guiding students' interpretation of their experiences. The students were presented a few times during the instruction with phenomena that cannot be explained by their commonly held ideas and were challenged to explain these phenomena. Students responded to written diagnostic questionnaires at the beginning of the study and four months later, at the end of the instruction. The probes used in the questionnaires and interviews were designed to reveal conceptual understanding of the concepts of natural selection and the inheritance of traits. The thirteen students that participated in the study varied greatly in their abilities and motivation. Students that were interviewed (four in total) were selected mainly on the basis of their abilities to articulate their ideas in a clear and open manner.

Findings

At the beginning of instruction, all students demonstrated naïve ideas related to the mechanism of natural selection, though the number and type of naïve ideas held by each student varied. At the end of instruction, different patterns of conceptual change were observed:

- Half of the students expressed naïve conceptions at the end of instruction and those ideas were intertwined with scientifically accepted components.
- None of the students in this study referred in their explanation to all 'components' of a scientifically accepted explanation. That is, none of the students provided a full, rich explanation.
- Multiple task contexts used to probe the mechanism of natural selection elicited responses that were very different from one another.

This study supports the view of Driver, Newton, & Osborne that conceptual change is dependent on the opportunity to construct and reconstruct individual ideas through the process of dialogic argument (Driver et al, 2000). Our results suggest that the students did not undergo a process of 'holistic' conceptual change in which one comprehensive conception is replaced by a new, more persuasive one. In most cases, less dramatic changes—such as the addition of a scientific component or term to an existing naïve idea—took place. These results support previously reported studies that suggested that different models of conceptual restructuring are possible (Settlage, 1994; Demastes et al, 1996). The inconsistency of responses across the multiple probes that were used, imply that students ideas are neither systematic nor coherent, much as described by diSessa (diSessa, 1993; Southerland et al, 2001). Instead, students' knowledge consists of fragments that learners use in an unconscious way in response to a particular situation.

14.30 - 17.00: Symposia

A. Conceptual Change in Mathematics: Theoretical Issues and Educational Applications

Organizers: Kaarina Merenluoto, University of Turku, Finland; Xanthi Vamvakoussi, University of Athens, Greece

Chair: Stella Vosniadou, University of Athens, Greece

Discussant: Anna Sfard, University of Haifa, Israel

In this symposium, we explore different aspects of the conceptual change approach to learning, with relevance to mathematics learning. Both theoretical issues and educational applications are treated by the participants of the symposium. We further explore the power of this approach in describing and explaining conceptual difficulties in the development of mathematical concepts. We discuss about metacognitive aspects of the conceptual change theoretical approach. We also discuss about the challenges of the educational applications of the conceptual change theoretical framework. More specifically: Dina Tirosh and Pessia Tsamir explore the similarities and differences of the conceptual change approach and Fischbein's theory of intuitions (Fischbein, 1987), with respect to the concept of infinity. In their presentation, Xanthi Vamvakoussi and Irene Biza will describe the development of the mathematical concepts of the tangent of a curve and the rational numbers' density in terms of the conceptual change theory proposed by Vosniadou (1994, 2001). Kaarina Merenluoto seeks the traces of conceptual change in the learning history of professional mathematicians, as they recall it themselves. Finally, Wim Van Dooren reports the results of a teaching experiment, aiming at facilitating students to overcome the "illusion of linearity".

References

Fischbein, E., (1987). Intuition in science and mathematics: An educational approach. Dordrecht, The Netherlands: Kluwer.

Vosniadou, S. (1994) Capturing and modelling the process of conceptual change. In S. Vosniadou (Guest Editor) *Conceptual Change*. *Special issue of Learning and Instruction*, 4, 45-69.

Vosniadou, S. (2001). On the Nature of Naïve Physics. In M. Limon and L. Mason (Eds.). *Reframing the Processes of Conceptual Change*. Kluwer Academic Publishers.

An Application of the Conceptual Theory to the Comparison of Infinite Sets

Dina Tirosh and Pessia Tsamir, Tel Aviv University, Israel

Difficulties arise when we attempt, with our finite minds, to discuss the infinite, assigning to it those properties which we give to the finite and limited

Galileo, 1954/1638, p. 31.

The theoretical framework of conceptual change is widely used to explain students' learning difficulties in science education and to design learning environments for science instruction (e.g., Vosniadou, 1994; Vosniadou, Ioannnides, Dimitrakopoulou & Papademetriou, 2001). In the last years several researchers attempted to explore the promises of this theoretical framework to mathematics learning and teaching (Verschaffel & Vosniadou, in press). Most studies explored the conceptual changes involved in the transition from one number system to a wider one (e.g., from natural numbers to fractions, to rational numbers and to negative numbers – Stafylidou & Vosniadou, in press; Hartnett & Gelman, 1998; Vamvakoussi & Vosniadou, in press; Vlassis, in press). In our presentation we shall discuss the applicability of the conceptual change approach to the learning and teaching of Cantorian Set Theory. We shall focus on one major aspect of this theory: the equivalency of infinite sets. The terms "comparing infinite sets", "comparing infinte quantities" and "determining the equivalency of infinite sets" are used interchangebly to accout for the comparison of the powers of these sets.

The Cantorian Set Theory is the most commonly used theory of infinity today. Yet, studies have shown that students face great difficulties in acquiring various properties of the equivalency of infinite sets (Fischbein, Tirosh & Hass, 1979; Duval, 1983; Borasi, 1985; Tirosh, 1991; Tsamir, 1999; Lakoff & Nunez, 2000). These studies pointed at the profound contradictions between the properties of infinite sets and our intellectual schemes, which are naturally adapted to finite objects and finite events (e.g., there are as many odd numbers as natural numbers, the number of points in a line segment is greater than the number of natural numbers). These and other studies reported that when asked to compare the number of elements in two infinite sets students at different grade levels used methods that are adequate only for the comparison of the number of elements in finite sets to compare the infinite ones. It seems evident from the related research findings and also from the historical development of Cantorian Set Theory that the acquisition of various aspects of the theory in general and the equivalency of infinite sets, in particular, necessitate radical construction.

In the course of the last twenty years we designed and evaluated several instructional practices for Cantorian Set Theory (Tirosh, Fischbein & Dor, 1985; Tirosh, 1991; Tsamir & Tirosh, 1999; Tsamir, 1999, 2003). These instructional practices were inspired by Fischbein's (1987) theory of intuition in mathematics and science. The major principles that guided the development of these instructional practices (as described, for instance, in Tirosh, 1991) were:

- Identifying the intuitive criteria that students use to compare infinite quantities
- Raising students' awareness of inconsistencies in their own thinking,
- Discussing the origins of students' intuitions about infinity,
- Progressing from finite to infinite sets,
- Stressing that it is legitimate to wonder about infinity,
- Emphasizing the relativity of mathematics,
- Strengthening students' confidence in the new definitions.

We evaluated the impact of various courses, including traditional courses with little or no emphasis on students' intuitive tendencies to overgeneralize from finite to infinite sets, and courses that were developed in line with the principles listed above, on high-school students and on prospective mathematics teachers' intuitive and formal knowledge of Cantorian Set Theory. We found that various types of synthetic models were developed during instruction in the different groups of learners. However, while most of those who studied in the traditional courses exhibited such synthetic models after instruction, only a limited number of those who participated in the specifically designed courses continued to hold such models.

It is evident from this short outline that there are several similarities between the conceptual change approach and Fischbein's theory of intuitions. In the presentation we shall compare and contrast the two theories.

References

Borasi, R. (1985). Errors in the enumeration of infinite sets. *Focus on Learning Problems in Mathematics*, 7, 77-89.

Duval, R. (1983). L'Obstacle du dedoublement des objets mathematiques. *Educational Studies in Mathematics*, 14, 385-414.

Fischbein, E., (1987). Intuition in science and mathematics: An educational approach. Dordrecht, The Netherlands: Kluwer,

Fischbein, E., Tirosh, D., & Hass, P. (1979). The intuition of infinity. *Educational Studies in Mathematics*, 10, 3-40.

Galileo, G. (1954/1638). *The new sciences* (H. Crew and A. Salvio, Trans.), Dover, New York (previously published 1811).

Hartnett, P., & Gelman, R. (1998). Early understanding of numbers: Paths or barriers to the construction of new understanding? *Learning and Instruction*, 8 341-374.

Lakoff, G. & Nunez, R. (2000).Where mathematics comes from: How the embodied mind brings mathematics into being, (pp.155-333). New York: Basic Books.

Stafylidou, S. & Vosniadou, S. (in press). Students' understanding of the numerical value of fractions: A conceptual change approach. *Learning and Instruction*.

Tirosh, D., Fischbein, E., and Dor, E. (1985). The teaching of infinity. In L. Steefland (Ed.), *Proceedings of the 9th Conference of the International Group for the Psychology of Mathematics Education* (pp. 501-506). Utrecht, The Netherlands: University of Utrecht.

Tirosh, D. (1991). The role of students' intuitions of infinity in teaching the Cantorian theory. In D. Tall (Ed.), *Advanced mathematical thinking* (pp. 199-214). Dordrecht, The Netherlands: Kluwer.

Tsamir, P., and Tirosh, D. (1999). Consistency and Representations: The case of actual infinity. *Journal for Research in Mathematics Education*. 30, 213-219.

Tsamir, P. (1999). The transition from the comparison of finite sets to the comparison of infinite sets: Teaching prospective teachers. *Educational Studies in Mathematics*, 38, 209-234.

Tsamir, P. (2003). From "easy" to "difficult" or vice versa: The case of infinite sets. *Focus on Learning Problems in Mathematics*, 25, 1-16.

Vamvakoussi, X., & Vosniadou, S. (in press). Understanding the structure of the set of rational numbers: A conceptual change approach. *Learning and Instruction*.

Verschaffel, L., & Vosniadou, S. (in press). The conceptual change approach to mathematics learning and teaching. *Learning and Instruction*.

Vlassis, J. (in press). Making sense of the negative sign or becoming flexible in "negativity". Learning and Instruction.

Vosniadou, S. (1994). Capturing and modelling the process of conceptual change. In S. Vosniadou (Guest Editor) Special Issue on Conceptual Change. *Learning and Instruction*, 4, 45-69.

Vosniadou, S., Ioannnides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction*, 11, 381-420.

Understanding Density: Presuppositions, Synthetic Models and the Effect of the Number Line

Xanthi Vamvakoussi* and Stella Vosniadou, University of Athens, Greece

Introduction

Already at a very young age, children have formed what has been characterized as "principled understanding" of natural numbers (Gelman, 2000), which is based on the act of counting. A basic characteristic of this initial "theory" of numbers is that numbers are discrete in nature. In fact, there is evidence that the property of discreteness of numbers may be neurobiologically based, in the sense that humans are prepared to learn and reason with natural numbers (Dehaene, 1998; Gelman, 2000). In the first years of mathematics education, children's informal knowledge about natural numbers is further confirmed and strengthened. There is plenty of evidence that, when new knowledge about rational numbers is to be acquired, prior knowledge about natural numbers may inhibit further understandings. These are the cases in which what is to be learned comes in conflict with what is already known. One such case is the development of the concept of density of rational numbers.

Understanding the structure of the set of rational numbers: A conceptual change approach

Contrary to the set of natural numbers, the set of rational numbers is dense: Between two successive natural numbers there is no other natural number, whereas between any two, non equal, rational numbers, there are infinitely many numbers. This is not in accordance with students' prior knowledge. Moreover, the idea of discreteness is deeply rooted into the human mind. In terms of the conceptual change theoretical framework proposed by Vosniadou (1994, 2001), discreteness is a fundamental presupposition of children's initial "theory" of numbers. In previous work (Vamvakoussi and Vosniadou, in press), we have assumed that understanding of density requires conceptual change. Qualitative data from a study with 16 ninth graders supported our hypothesis. According to our results,

- the majority of students generated errors that reflected the presupposition of discreteness. For example, students answered that "there is no other number between 0.005 and 0.006, because 0.006 comes immediately after 0.005" or that "there is only one number between 3/8 and 5/8, namely4/8".
- we diagnosed intermediate levels of understanding, reflecting students' efforts to assimilate new information about rational numbers, in their pre-existing structures of knowledge about natural numbers. For example, some students answered that "between 0,005 and 0,006 there are 0.0051, 0.0052, up to 0.0059". One student answered that there is finite number of numbers between decimals, but "if you turn them into fractions, then you find infinitely many numbers in between". Other students implied that between two fractions, there are infinitely many fractions. According to other students, different symbolic representations of the same number, e.g. 4/8, 8/16 etc. can count as infinitely many different numbers.

To summarize, the idea of discreteness seems to be a fundamental presupposition, which shapes students' understanding of the structure of the set of rational numbers. Yet, the development of the concept of density seems to be constrained by other parameters, too.

The empirical study

Based on the findings of the first study, we assumed that students' understanding of the structure of the set of rational numbers is also constrained:

- by their belief that different symbolic representations of the same number refer to different numbers.
- by their disposition to group numbers together on the basis of their symbolic representations.

To test these assumptions, we conducted an empirical study. We also aimed at investigating the effect of the number line on students' responses to questions about density. the participants of this study were 301 students, 164 ninth and 137 eleventh graders, all from schools in the Athens area. Based on the materials of the first study, we designed two types of questionnaires, a forced-choice questionnaire and one with open ended questions.

According to our results,

- the idea of discreteness is still strong in the case of eleventh graders.
- giving up the idea of discreteness is not an "all or nothing situation". For instance, the knowledge that there are infinitely many numbers between two decimals is not necessarily transferred to the case of fractions.
- students who answer that there are infinitely many numbers between two rational numbers, regardless of their representation, may still be constrained by the symbolic representation of the particular numbers. For instance, they may answer that "there are infinitely many fractions between two fractions.
- the belief that different symbolic representations of a number refer to different numbers is reflected in the answers of students of various levels of performance in the questionnaire.
- the effect of the number line on students' performance seems quite limited. Moreover, the effect "disappears", when the number line is taken away.

We will present these results and we will argue that students' misconceptions about density can be accounted for by the three assumptions mentioned above (the fundamental presupposition of discreteness, the belief that different symbolic representations of a number refer to different numbers and the disposition to group numbers of the same symbolic representation together). We will also argue that, students' misconceptions can be explained as synthetic models, since they reflect students' efforts to assimilate new information about rational numbers in their prior knowledge structures about natural numbers. Finally, we will attempt to explain why a widely used external representation of real numbers, namely the number line, seems to have a limited effect on students' understanding about density.

References

Dehaene, S. (1998). *The number sense: How the mind creates mathematics.* Harmondsworth Middlesex England: The Penguin Press. First published by Oxford University Press, 1997.

Gelman, R. (2000). The epigenesis of mathematical thinking. *Journal of applied developmental psychology, 21(1)*, 27-37.

Vamvakoussi, X. & Vosniadou, S. (in press).Understanding the structure of the set of rational numbers: A conceptual change approach. *Learning and Instruction.*

Vosniadou, S. (1994) Capturing and modelling the process of conceptual change. In S. Vosniadou (Guest Editor) *Conceptual Change*. *Special issue of Learning and Instruction*, 4, 45-69.

Vosniadou, S. (2001). On the Nature of Naïve Physics. In M. Limon and L. Mason (Eds.). *Reframing the Processes of Conceptual Change*. Kluwer Academic Publishers.

Conceptual Change in Calculus: From the Circle's Tangent to a Curve's Tangent

Irene Biza*, Alkeos Souyoul and Theodossios Zachariades, University of Athens, Greece

In this paper, we argue that a conceptual change approach could interpret some of the misconceptions dealing with the concepts of curve's tangent and derivative. In a pilot study, we make a case that students take for granted properties of circle's tangent in curves, where they do not apply in general. It seems that students generate resistant *synthetic models* to deal with tangent's problems.

Theoretical background – The aim of the study

Conceptual change studies the process of knowledge acquisition and especially in situations where the prior knowledge is incompatible with the new one. Consequently, various misconceptions occur in a not arbitrary way (Vosniadou, 1994). Many studies investigate conceptual change in the learning process of mathematical concepts (e.g. Merenluoto & Lehtinen, 2002; Stafilidou & Vosniadou, in press; Vamvakoussi & Vosniadou, 2002). In this paper, we present the results of a pilot study of a research concerning the development of notions of advanced mathematical thinking, from the conceptual change point of view. In particular, it

deals with the concept of derivative and its geometrical representation, which is related to the notion of tangent line.

The notion of the tangent line appears in three stages during a student's schooldays. In geometry where students learn the tangent of the circle as a line, that has exactly one point, common with the circle. An intuitively obvious property of this line is that it divides the plane in two parts, one of which contains the whole circle. Later, the students are introduced to the conic sections. In these cases, the tangent's definition is different; it is more sophisticated. The "exactly one common point" property remains true in conics, but it is not enough to define the tangent. The "residence on one semi-plane" property is not valid in the case of the hyperbola but it remains true for each branch separately. Therefore, students do not change the previous intuitive images essentially. Finally, in a calculus course students encounter the concept of tangent to a point on a curve. Generally, none of the above properties remains valid. In fact, there are functions that have a tangent that not only does it have more than one intersection points with the curve, but it also splits the curve into two or more pieces (graph B6). At this level, a curve's tangent is defined through the concept of derivative. However, students usually have a *concept image* of tangent, involving circle–like pictures. These concept images cause some of the misconceptions found in the case of a curve's tangent (Vinner, 1991).

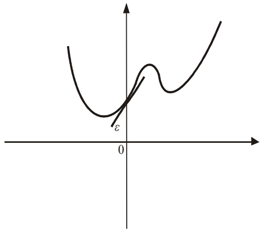
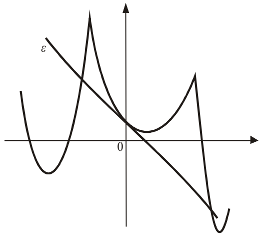
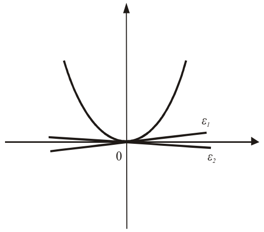
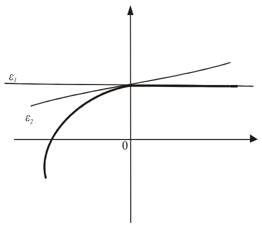
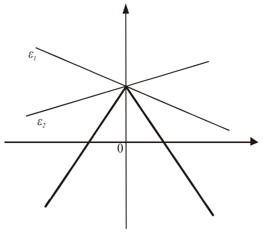
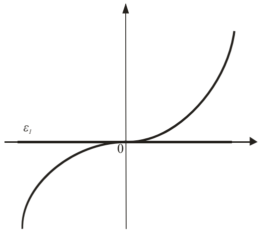
In terms of the theory of conceptual change that Vosniadou (1994) proposes, we argue that the ideas related to the notion of the circle's tangent are fundamental presuppositions, which act as a barrier to the process of mastering the notion of curve's tangent. Students usually generate *synthetic models* in their attempts to relate the information they receive about tangent with their knowledge on the circle's properties.

Methodology

The participants of this pilot study were 19 first year university students of mathematics, of various levels of performance. They answered a questionnaire and afterwards we had an interview with each one of them and discussed his/her answers. During the previous year, all of these students had an introductory calculus course at school. By the time we interviewed them, they had not been taught these concepts at a university level.

Findings

In the part of the questionnaire dealing with the tangent of a curve at a point, students were asked to determine which of the drawn lines are tangent at zero.


B1

B2

B3

B4

B5

B6

Through the students' answers to the questionnaire and the interviews, we categorized them into three groups, according to the extent that the "exactly one common point" and the "residence on one semi-plane" properties, dominate their thoughts about tangent. In the first group, students use these properties to characterize the concept of tangent and in some cases they use them as a definition. They reject some correct tangents as B2 or B6 and accept as tangents, lines that are not as B3 or B5. Students in the second group have created a more sophisticated concept image of tangent. They check the validity of the above properties locally. A curve can have a tangent at a point, if there is a neighborhood around that point, where the curve "seems like a circle". For them, ε is the tangent of the curve in B2, whereas ε_1 in B4 or B6 is not. The students of this group have made a *synthetic model* of both the circle and curve's tangent, in their attempts to deal with the tasks of the questionnaire. A few students belong to the third group, having no problem to recognize a correct tangent, with no regard to whether the two properties are true.

Discussion

Although this is just a pilot study, we believe that it could offer some evidence to support our assumptions. This pilot study has suggested that acquisition of knowledge of tangent line requires a conceptual change. This is a complex and discontinuous process. We tend to believe that the main presuppositions related to the circle model are "exactly one common point" and "residence on one semi-plane". These properties are inherited from the circle and they are obstacles to the process of transition to a generalized notion of tangent, since they are not

connected to the *local straightness,* which is the *cognitive root* for the notion of derivative, according to Tall (1989, 2003).

References

Merenluoto, K., & Lehtinen, E. (2002). Conceptual change in mathematics: Understanding the real numbers. In Limon, M. & Mason, L. (Eds.) *Reconsidering conceptual change: Issues in theory and practice*, (pp.233-258). Dodrecht: Kluwer Academic Publishers.

Stafylidou, S., & Vosniadou, S. (In press). The development of Students' Understanding of the Numerical Value of Fractions In Special Issue on Conceptual Change. Learning and Instruction.

Tall, D. (1989). Concept Images, Computers, and Curriculum Change. *For the Learning of Mathematics*, 9,3 37–42.

Tall, D. (2003). Using Technology to Support an Embodied Approach to Learning Concepts in Mathematics. In L.M. Carvalho and L.C. Guimarães *História e Tecnologia no Ensino da Matemática*, vol. 1, pp. 1-28, Rio de Janeiro, Brasil.

Vamvakoussi, X., & Vosniadou, S. (2002). Conceptual change in Mathematics: From the set of natural to the set of rational numbers. *Proceedings of the Third European Symposium on Conceptual Change, Turku, Finland.*

Vinner, S. (1991). The role of definitions in the teaching and learning of Mathematics. *Advanced Mathematical Thinking*, 65-81.

Vosniadou, S. (1994). Capturing and modelling the process of conceptual change. In S. Vosniadou (Guest Editor) Special Issue on Conceptual Change. *Learning and Instruction, 4*, 45-69.

Retrospective Interviews of Experts in Mathematics - Suggesting Conceptual Change

Kaarina Merenluoto, University of Turku, Finland

The aim of this study is to explain, if there are indications for conceptual change in the retrospective interviews of professional mathematicians when they explain their learning history and their everyday use of numbers. Eight university mathematicians participated to interviews which were tape recorded and qualitatively analysed.

Introduction

Conceptual change is used to characterize situations where learners' prior knowledge is incompatible with the new conceptualization, where learners are often disposed to make systematic errors or build misconceptions and where the learner's prior knowledge restricts the acquisition of new conceptual understanding (e.g. Vosniadou, 1999). According to several studies (e.g. Merenluoto & Lehtinen, 2002) the extension of number concept from natural numbers to the domain of rational numbers means a radical conceptual change for the learner because of the underlying fundamental difference between these number domains.

The essence of natural numbers is their discrete nature, which means that for every number a successor is defined and that no two numbers have the same successor. But for rational numbers a successor is not defined because the rational numbers are defined as a relation where infinite successive division is possible. At lower levels of mathematical education, this extension of the number concept demands new rules to be learned for operations and the use of a new kind of logic often leading to many different, but systematic problems and misconceptions in mathematics learning.

In later development of the conceptual change in the number concept, the extensions of the number domains is a continuous process of vertical hierarchical abstractions, where at the next phase rational numbers are treated as subsets of real numbers, the real numbers as subsets of complex numbers etc. The notion of real numbers is one of the most complex and profound concepts in mathematics. The mathematicians have several different rigorous definitions for them, such as defining them as a limit of a sequence or a cut of the number line. In addition to the high complexity of the concepts; the symbolic language of mathematics tries to describe all concepts in a very economical way. However, all the concepts get their meaning from a large and often highly abstract system of interrelated ideas. There are many mathematical concepts which cannot be understood on the basis of prior formal knowledge but the very understanding of the concept presupposes the construction of this abstract systemic environment (Landau, 1951/1960). Thus, the indications to conceptual change are possible even on advanced levels of mathematics.

Results

In explaining their learning histories, some of the mathematicians spontaneously referred to very early mathematical discoveries, such as understanding the system of negative numbers as three years old while inspecting the numbers in the thermometer. When explaining their learning history they referred to 1) their experiences of beauty and excitement in mathematics as indications of their interest to the domain; 2) their learning strategies as indications of their intentionality; and also to the changes in epistemology of mathematics.

In the retrospective interviews that they did not spontaneously remember any particular difficulties in the extension of their number concept during their school years; the density of numbers was easily understood by using the model of the number line. The first difficulties for some of them were the complex numbers. These numbers are not represented as points of the number line but as points of a plane defined by the real and imaginary axis. But, they explained, this difficulty was quickly solved in a few weeks. However, most of them clearly remember, and lively explained the difficulty they faced when they were introduced to university

mathematics referring to their introductory experience as "a crash" or "a knock out".

When the mathematicians described their thinking of numbers, they also made a clear distinction between the formal and informal presentations of real numbers. All of them referred to their understanding the formal representations of real numbers but they explained their thinking of real numbers with informal meta-level representations based on the basic underlying general principles in the abstraction of density (cf. the theories of expertise; Chi, Glaser & Farr, 1988). They explained real numbers as "a topological system", "approximations", "a neighbourhood system", "a density of points of the number line" or "as softened atoms" (referring to the non-standard analysis). They also clearly exclaimed how all the everyday numbers are rational numbers, and that the real numbers are only for theoretical purposes. In describing their everyday thinking of numbers they spontaneous referred to the number line and concepts of accuracy suggesting flexible strategies in dealing with numbers and attention to the underlying fundamental principles of real numbers (cf. Dreyfus 1991).

If contrasted to the descriptions of the students (novices) at upper secondary level (Merenluoto & Lehtinen, 2002); there were clear distinctions in the nature of mathematical argumentation, in the nature of mathematical activity; in forming several alternative frameworks for numbers. The results also suggest important changes in the epistemology in the advanced level of mathematics thinking.

References

Chi, M. T. H., Glaser, R., & Farr, M. F. (1988). The nature of expertise. Hillsdale, NJ: Lawrence Erlbaum.

Dreyfus, T. (1991). Advanced mathematical thinking processes. Teoksessa D. Tall (toim.) *Advanced mathematical thinking*. Dordrecht: Kluwer Academic Publishers, 25-41.

Landau, E. (1960/ 1951). Foundations of analysis. The arithmetic of whole, rational, irrational and complex numbers. New York: Chelsea Publishing.

Merenluoto, K., & Lehtinen, E. (2002). Conceptual change in mathematics: Understanding the real numbers. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change. Issues in theory and practice* (pp. 233-258). Dordrecht: Kluwer Academic publishers.

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

The Illusion of Linearity: A Misconception Requiring Conceptual Change?

Wim Van Dooren*, Dirk Janssens and Lieven Verschaffel, University of Leuven, Dirk De Bock and An Hessels, National Fund for Scientific Research, Belgium

Introduction

Already at a very young age, children experience the wide applicability and intrinsic simplicity of linear/proportional relations. In primary and secondary school mathematics education, moreover, extensive attention is paid to this type of relations. The early acquisition and repeated confirmation of the linear model, in the long run, causes a deeply entrenched misbelief that almost every relation between two quantities is proportional, and that proportions are a panacea for nearly all problems. This phenomenon is called the "illusion of linearity".

Utterances of this "synthetic model of linearity" are manifold: they are found at different age levels and in different mathematical domains (e.g., geometry, probability, algebra, elementary arithmetic, calculus) but also in sciences (e.g., physics). Recent empirical studies showed the overgeneralisation of linearity in upper secondary school students' probabilistic reasoning (e.g., believing that the chance of getting a six in rolling four dice is double as large as the probability of getting a six in rolling two dice) (see Van Dooren, De Bock, Depaepe, Janssens, & Verschaffel, 2003) and in elementary school students' arithmetic problem solving (e.g., students answering "90 rounds" to the following problem: "Ellen and Kim are running around a track. They run equally fast but Ellen started later. When Ellen has run 5 rounds, Kim has run 15 rounds. When Ellen has run 30 rounds, how many has Kim run?").

The illusion of linearity in geometry

Most empirical evidence on the illusion of linearity focuses on one particular misbelief within the context of geometry, namely the conviction that if a geometrical figure enlarges *k* times, its area and/or volume become *k* times larger too (e.g. the belief that if the diameter of a circle is tripled, the area is also tripled). We conducted a systematic series of empirical studies on this phenomenon.

The first goal of the current paper is to investigate to what extent students' illusion of linearity in this geometrical context can be explained in terms of the conceptual change theory. Do the key assumptions of the conceptual change theory (early acquisition and repeated confirmation of knowledge elements, existence of deeply entrenched presuppositions, unavailability to conscious awareness, hindering later learning, arise of misconceptions) hold for the illusion of linearity as well? An answer will be given by means of results of the following empirical studies:

In a first series of studies (see, e.g., De Bock, Verschaffel, Janssens, Van Dooren, & Claes, 2003), large groups of 12-16-year old students solved paper-and-pencil tests under different experimental conditions. These tests contained problems like "*Farmer Carl needs approximately 8 hours to manure a square piece of land with a side of 200 m. How many hours would he need to manure a square piece of land with a side of 600 m?*" The vast majority of them failed in solving problems due to linear reasoning (i.e. in this case: "the side is tripled, so the amount of time to manure the piece of land is tripled"). Even with considerable support (e.g., drawings or metacognitive stimuli), only very few students made the shift to correct non-linear reasoning. Moreover, the students who made the shift to non-linear reasoning for these non-linear problems, sometimes started to apply these non-linear solution schemes to linear problems too.

A subsequent study by means of in-depth interviews with 40 12-16-year olds (De Bock, Van Dooren, Janssens, & Verschaffel, 2002) showed that the students are often unaware of their assumption of linearity, and that it is not subject to deliberate hypothesis testing. Moreover, students had particular shortcomings in their geometrical knowledge base, and showed some inadequate habits, beliefs and attitudes towards mathematical problem solving, which hindered the discovery of the correct mathematical principles.

A teaching experiment striving for conceptual change

In the second part, we will describe a teaching experiment aiming at conceptual change in 13-14-year old students. We developed and tested a 10-hour lesson series to help these students overcome the illusion of linearity. The learning environment was developed based on the instructional design principles derived from the conceptual change approach (see, e.g., Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001), such as: (1) taking into account students' prior knowledge, (2) explicitly addressing students' preconceptions, (3) facilitating students' metaconceptual awareness and metacognition, (4) providing adequate motivation sources and (5) providing adequate mathematical models and external representations.

Students' learning progress was tested using a pretest-posttest-retention test design with an experimental group and a control group. The results are both promising and disappointing. While students often no longer automatically applied the linear model to area and volume problems, they suddenly started to apply quadratic or cubic strategies to perimeter problems too. Moreover, several other students still continued to apply linear strategies for non-linear problem situations. Students' prior knowledge interfered with the lesson contents, and often students did not acquire a deep conceptual understanding of (the difference between) linear and non-linear relations and the situations where they apply.

References

De Bock, D., Van Dooren, W., Janssens, D., & Verschaffel, L. (2002). Improper use of linear reasoning: An in-depth study of the nature and the irresistibility of secondary school students' errors. *Educational Studies in Mathematics, 50*, 311-334.

De Bock, D., Verschaffel, L., Janssens, D., Van Dooren, W., & Claes K. (2003). Do realistic contexts and graphical representations always have a beneficial impact on students' performance? Negative evidence from a study on modelling non-linear geometry problems. *Learning and Instruction, 13*, 441-463.

Van Dooren, W., De Bock, D., Depaepe, F., Janssens, D., & Verschaffel, L. (2003). The illusion of linearity: Expanding the evidence towards probabilistic reasoning. *Educational Studies in Mathematics, 53*, 113-138.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*, 381-419.

B. Conceptual Change in Physics: The Learner's Modeling of the Physical World

Organizers: Ola Halldén and Gunilla Petersson, Stockholm University, Sweden

Chair: Gunilla Petersson, Stockholm University, Sweden

Discussant: Ola Halldén, Stockholm University, Sweden

In 1976 Driver and Easley presented their survey of research from which they concluded that a learner interpret the physical world out of a conceptual framework different from that fostered in science. For example, the layman's concept of force is embedded in another conceptual framework than the concept of force in physics. Since then there has been a debate whether these alternative frameworks are that consistent and that stable that they qualify for be regarded as some sort of laymen's theories or if they are just to be looked at as weakly organised sets of presuppositions actualised by salient features in different situations.

In research on conceptual change there have been attempts to describe the structure of intuitive conceptual frameworks. In a special issue of *Learning and Instruction*, 1994, on Conceptual change in the physical sciences, edited by Stella Vosniadou, different ways of describing such knowledge structures were presented by different authors. For example, Tiberghien described conceptual structure at three different levels, i.e. the level of theory, the level of model, and the field of applicability, respectively. Conceptual change, then, involves relating these levels to one another according to physics rather than according to intuitive commonsense knowledge. Recently, diSessa and Sherin have proposed a model of coordinating classes that also is claimed to take into account different ways of experiencing the physical world in a similar way that the level of model and theory do in Tiberghien's model.

Thus, there are aims during the last decades to solve the question of the nature of conceptual frameworks actualised by the article by Driver and Easley. The symposium aims at bringing this question a bit further and is thus focussing on descriptions of conceptual systems and their relationships to the physical world as well as to the process of conceptual change.

Modeling the Didactical Activities in Physics

Dimitrios Psyllos*, Aristotle University of Thessaloniki, and Vassilis Tselfes, University of Athens, Greece

In the present paper we assume that the connection between the literal-representational aspect of scientific knowledge and the practical-interventionist should be included in the aims of science education. In line with studies of scientific practices, we claim that there are three major categories of entities internal to scientific inquiry. These are: material entities which we call Cosmos; Evidence as considered appropriate by the experimenter and Ideas about the natural phenomenon under consideration. We consider that modelling practices of scientific inquiry in terms of patterns of connections between the entities of Cosmos, Evidence and Ideas does not apply only to professional settings but to educational ones as well. Accordingly, we discuss the CEI model as a theoretical framework appropriate for an epistemological modelling of didactical activities. This model shows not only the entities but also the fact that during the course of inquiry scientific activities involve two-way interactions between entities. The employment of the CEI model has the advantage of allowing a – fruitful for science teaching – distinction to be drawn between interventions onto the material world and representations of the material world since the model discerns between the connections in which, potentially, the linguistic factor holds the most important role and the ones where the material factor should be expected to be more important. As to how such connections would be made effective, we argue that social constructivist approaches would be beneficial in the case of activities in which human interaction dominates, while on the other hand for activities in which interaction between the human and the material factor prevails, individual (cognitive) constructivist approaches would prevail. In the presentation we provide examples of applying the CEI model for the analysis and design of didactical activities in physics.

How Students Develop and Use an Explicit Understanding of Physics Concepts

Claudia von Aufschnaiter, University of Hannover, Germany

Research on students' conceptions and conceptual change has had a large impact on research into teaching and learning processes particularly within science. One theoretical assumption underlying this research seems to be that all types of learner activity are based on conceptual understanding which may or may not match the "correct" scientific concept. However, little effort has been made to investigate whether this assumption is a viable description of the *processes* occurring during learning. At the universities of Bremen and Hannover several studies have been carried out aiming to describe in detail students' development and usage of physics knowledge. The studies include more than 200 participants aged between 13 and about 25 years. Students' (verbal) activities while working in groups on physics tasks or while following physics instruction were recorded with video and investigated using the dimensions of content, complexity, and time. Furthermore, to explore the nature of conceptual development in more detail a system of categories has been developed which divides students' processes into explorative, intuitive rule-based, and theoretical rule-based activities. Results indicate that, for most of the time, students of all age groups did not refer to any kind of theoretical knowledge. Instead, students developed an intuitive understanding of the phenomena they were working on. Explicit theory-based conceptualisations occasionally followed intuitive understanding but were mainly not used in advance to predict the outcome of physics experiments.

Conceptual Change and the Changing Functions of Commonsense Physics Knowledge

Bruce Sherin, Northwestern University, USA

As humans, we all possess substantial knowledge concerning the workings of the physical world. We have interacted with the world on a daily basis, pushing and pulling objects, mixing liquids, and digesting food. This informally gained knowledge of the physical world has been given a variety of names in the research literature. Here, I refer to this as *intuitive* or *commonsense* physics knowledge.

Over the last two decades, researchers in science education have devoted substantial effort to the study of intuitive physics knowledge (Clement, 1984; diSessa, 1993; Halloun & Hestenes, 1985; McCloskey, 1983; McDermott, 1984). Underlying the interest in intuitive knowledge is the presumption that, in some manner, this knowledge is relevant to the learning of school physics. There are a range of possible ways in which intuitive knowledge might be relevant to science learning. For example, in some prominent literature, it is assumed that intuitive knowledge simply poses an obstacle to the learning of formal science knowledge. An alternative view asserts that intuitive knowledge must evolve during the learning of school physics, and that an adapted version of intuitive knowledge, augmented with additional knowledge of other types, continues to exist throughout learning. If we accept the latter view, then the central problem for research in conceptual change in physics is to understand this evolution of intuitive physics knowledge.

The principle claim of this paper is that, in order to construct an account of conceptual change in physics, it is essential that we understand the specific *function* that intuitive physics knowledge plays in formal expertise. Typically,

conceptual change in physics has been studied using qualitative problems; novices and experts are given questions about motion and forces, and they are asked, without using any numbers, to make qualitative predictions. This research has documented, in multiple ways, that instruction often does not impact commonsense physics knowledge, as evidenced in these qualitative questions.

But these qualitative questions are not the focus of formal physics instruction, nor are they the focus of expert physics practice. In formal physics instruction, students learn to solve certain types of quantitative problems, which almost always involve the application and manipulation of equations. Thus, a principle question for conceptual change research must be to understand the functions of intuitive knowledge within these formal tasks; we must attempt to delineate the roles, if any, that commonsense physics knowledge plays within formal physics problem solving. If we can map out these roles, then we will have the outlines of an account of how intuitive physics knowledge must change as expertise develops.

In this presentation, I will draw upon a corpus of videotaped interviews in which pairs of university physics students are asked to solve a range of physics problems. The presentation rests, in part, on systematic analyses of this corpus that have been published elsewhere (Sherin, 2001). Here, I will draw on these analyses and data corpus selectively, using examples from the corpus to support a number of points. First, I will attempt to make the case that intuitive physics knowledge plays a central role in the solving of formal physics problem solving; it is not only involved in the set up of a problem, it is employed throughout the process of problem solving. Most dramatically, commonsense physics knowledge provides schematizations that are directly associated with structures in equations. As argued in (Sherin, 2001), these schematizations direct the construction of new equations, and they are involved in the interpretation of existing equations.

Once I have established these points about the functions of commonsense knowledge in formal problem solving, I will present my best speculations concerning how intuitive physics knowledge must change in order to perform these functions.

Internalization of a Socially Shared System: Learning Science from Teaching Models

Marianne Wiser, Clark University, USA

Microworlds are computer-based, interactive models with which students learn the basic elements of a physics domain; they are cultural tools. Internalizing microworlds is both a social and a cognitive process: students learn the scientific theory by actively and dialectically constructing interpretations of the microworld on the basis of the knowledge they already have, and of discussions with their peers and teacher.

In a case study, four eighth-graders explored a thermal physics microworld. The protocols show three phases in their internalization of the microworld, corresponding to different understandings of the goals of the activities they were engaged in, of the function of models, of the relation between models and world, and between student's and scientist's perspectives. Students move from seeing the models themselves as the object of enquiry; to learning about the physical world through the models, by co-structuring the events in the microworld and corresponding events in the physical world; and finally, to understanding that the models represent the scientist's interpretation of the world. This third step is necessary for ontological change to take place, and requires explicit teaching about the cultural function of models and negotiations between teacher and students aiming at the integration of student's and scientist's perspectives.

Thus what cognitivists call "radical conceptual change" can be recast in socio-constructivist perspective-microworlds allow the construction of shared meaning between students and scientists, through the causal interaction between the students' evolving understanding of models as tools and conceptualization of the physical world, within collaborative goal-directed activities.

Friday, May 21st

08.30 - 11.00: Keynote Addresses & Panel Discussion

Chair: Andreas Demetriou, University of Cyprus, Cyprus

Keynote Addresses

Conceptions of Learning and Teaching at University: Relationships with Study Strategies and Understanding

Noel Entwistle, University of Edinburgh, UK

This paper looks at research into conceptual change as it affects student learning at university level. It draws initially on a series of studies carried out into conceptions of knowledge and learning to establish a framework for considering how changes in such conceptions may influence the ways in which students tackle their academic work. Inventory surveys are used to show empirical relationships between conceptions of learning and differing ways of describing study behaviour and academic performance. Interview studies have looked at how students develop academic understanding and findings from these studies contribute to an emerging conceptual framework in this area of research.

Students' thinking and studying is, of course, influenced by the teaching they experience. And university teachers differ markedly in their conceptions of teaching and learning, so it is important to see how conceptions of teaching change, and how such changes may influence how students learn. This area of research is less well developed than research on students' conceptions but throws up interesting suggestions for discussion, particularly about the extent to which conceptions are rooted in disciplinary traditions and how competing pressures on academics affects their ability to translate their conceptions into effective action.

Learning Science with Models as Interaction between Content, Mathematical, Epistemological, and Metacognitive Knowledge

Marianne Wiser, Clark University, USA

Teaching science via models and modeling activities raises important questions about incommensurability, conceptual change (including ontological change), epistemological understanding, intentionality, and their interdependence. Teaching models embody (simplified versions of) scientific theories; as such, they are not directly interpretable by students who hold alternative conceptualizations incompatible with important components of the models, raising the Catch-22 question: How can models help students learn a scientific theory if they need the theory to understand the models?

I will review different pedagogical strategies to teaching with models in elementary to high-school grades (C.Smith, R. Lehrer & L.Schauble, B. White, W-M. Roth, M. Wiser and others). These include strategic triggering of student experiential knowledge; starting with models students can interpret in a scientific way and increasing their complexity and mathematization; bootstrapping reconceptualization via thought experiments, analogies, limiting case reasoning, and student modeling before introducing the models themselves; emphasizing measurement and mathematical modeling; peer collaborative discussions for converging on shared meanings; using models for scientific enquiry; including epistemological teaching about the role of models and the nature of science; and including teacher-students negotiations about the relation between students' and scientists' conceptualizations.

These pedagogies, directly or indirectly, recruit and channel specific aspects of students' prior knowledge to help them construct an interpretation of the models compatible with the scientific interpretation; lead students to reconceptualize a model from something construed to a lens through which to construe the world; recognize the need to address the distinction and relation between perceptual and objective properties, and between "everyday" and "scientific" languages; are based on an evolving interplay between content and epistemic knowledge; teach about the intentionality embodied in the use of models; and highlight the dialectical nature of co-structuring the models and corresponding events in the physical world.

The use of models in science teaching and learning bears both deep similarities and deep dissimilarities to the use of models in normal and revolutionary science.

Panel Discussion

Patricia Alexander, Universityof Maryland, USA
Erno Lehtinen, University of Turku, Finland
Margarita Limón, Universidad Autónoma de Madrid, Spain
George Maragos, University of Crete, Greece
Lucia Mason, University of Padua, Italy
Stella Vosniadou, University of Athens, Greece

11.30 - 13.30: Paper Sessions

A. Conceptual Change in Mathematics

Chair: Theodossios Zachariades, University of Athens, Greece

Discussant: Chronis Kynigos, University of Athens, Greece

Conceptual Change in the Transition from Arithmetic to Algebra

Konstantinos Christou* and Stella Vosniadou, University of Athens, Greece

In the transition from arithmetic to algebra, the system of signs that is being used is changing. The major difference among the systems of signs in algebra and arithmetic has to do with the symbols that stand for numbers. In algebra, literal symbols are used to stand for numerical values. The literal symbol represents the generalized number which is all the numbers. Many research worldwide (Kucheman 1981, Booth 1984, Stacey & Mac Gregor, 1997) have indicated that students face great difficulties understanding the use of literal symbols as mathematical objects. The purpose of this research is to investigate students' understanding of the use of literal symbols as mathematical objects and to evaluate the usefulness of approaching this question from a conceptual change point of view.

The conceptual change framework that will be adopted in this research is the one developed by Vosniadou (1994, 1999). The key definitional elements of this framework are:

- The knowledge acquisition process is not always a process of enriching existing structures. Sometimes the acquisition of new information requires the radical reorganization of what is already known.
- Learning that requires the reorganization of existing knowledge structures is more difficult and time consuming than learning that can be accomplished through enrichment. Moreover, it is likely that in the process of reorganization students will create misconceptions.

In students' prior knowledge of numbers the set of natural numbers is the most embedded set of numbers. In the set of natural numbers, there is a one to one correspondence between the symbol of a number and its arithmetical value. It is possible to represent a natural arithmetic value with different ways only if rational numbers are used. For example, the natural number 2 is the only natural number that stands for the arithmetical value 2. This arithmetical value can also be represented using rational numbers as 4/2, 6/3, . While in the arithmetic of natural numbers there is a one to one correspondence between the symbol and its arithmetical value, in algebra, every literal symbol represents all arithmetical values. Another property of the natural numbers that cannot be applied in other sets of numbers is that the smaller arithmetical value of a natural number is the unit. The conceptual change research in the domain of understanding the concept of number indicates that students think of all the numbers as natural numbers and apply to them properties of the natural numbers (Vamvakoussi 2002). This misconception of the students is responsible for a number of mistakes that also appear in higher grades.

According to the theoretical framework described above, the hypothesis of this research is that the previous knowledge of the properties of the natural numbers affects the way students interpret the use of letters as mathematical object when they are introduced to algebra. Students assign properties of the natural numbers to the literal symbols of algebra and that misconception brings mistakes.

Some first results from a research with students around the age of 13 and 14 (7th and 8th graders) indicate that students have difficulties to understand that the literal symbols could stand not for a specific number but for every number they know. Students tend to assign natural values to the literal symbols when they stand by their own and more rarely fractions, decimals and negative ones. Big percentages of students think of the unit as the smaller value of a literal symbol. The big average of students assigns negative values to the variable (-x). Likewise, most students believe that the value of (x) is always positive. On the other hand, when students are asked to assign values to the (a/b) most of them easily respond that all numbers are accepted as values for that symbol. The (a/b) can be easily interpreted by the students as a fraction if they assign natural values to a and b and they know that a fraction can be an integer or a decimal number.

An old finding from many researches (Kucheman 1981, Booth 1984), that students think of the literal symbols as symbols that stand for only one number – different symbols stand for different numbers, was examined by using many different questions in this research. It came out that students use the literal symbol univocally and they stick up for it with much persistence. This belief constitutes a fundamental presupposition which obstructs students from understanding the use of letter as generalized number.

This approach could explain students' difficulties in understanding and dealing with advanced mathematical concepts as functions, absolute value, graphs, in fields like analysis, algebra and analytic geometry where literal symbols are used extensively. It is very important for the students to be able to understand the generalized nature of the literal symbol that is used in mathematics for their future development of the mathematical concepts. This theoretical approach can give new elements about the way students give meaning to the use of literal symbols as mathematical objects.

References

Kuchemann (1981). Algebra. In K. M. Hart, (Ed.), *Children's Understanding of Mathematics*: *11-16* (pp. 102-119). London: John Murray

MacGregor, M. & Stacey K. (1997) Students' Understanding of Algebraic Notation: 11-15. *Educational Studies in Mathematics,* 33(1), 1-19.

Stacey, K. & MacGregor, M. (1997) Ideas about Symbolism that students bring to *Algebra. The Mathematics Teacher*, 90(2), 110

Vamvakoussi, X. & Vosniadou, S. (2002). Conceptual change in Mathematics: From the set of natural to the set of rational numbers. *Proceedings of the Third European Symposium on Conceptual Change, Turku, Finland*

Vosniadou, S., (1994). Conceptual Change in the Physical Sciences, *Special Issue of Learning and Instruction, Vol. 4*, 1

Vosniadou, S., (1999). Conceptual Change Research: State of the art and future directions. In Schnotz, W., Vosniadou, S. & Carretero, M. (Eds.) *New Perspectives on Conceptual Change*, (pp. 3-13). Elsevier Sciences Ltd.

Children's Understanding of Enlarging and Shrinking a Part of an Intensive Quantity

Despina Desli, Democritus University of Thrace, Greece

Intensive quantities refer to the constant relation between two variables and, therefore, involve different number meanings (Desli & Nunes, 1997; Desli, 2001) and have different implications when operations are carried out (Desli, 2002). Their understanding is basic to the understanding of many scientific and ordinary concepts: it is mainly connected to the ability to keep the equality in an intensive quantity, that is no to alter the value of the intensive quantity when the extensive quantities involved change. Whereas in extensive quantities, increasing or decreasing the amount refers to the 'how muchness' of the quantity, in intensive quantities the conservation of the quality can only be achieved in reference to the relation between the parts and the whole; this relation between the parts and the whole is connected to the conservation of the quality of the whole irrespective of the increases or decreases the whole has gone through. In the present study children's primary ideas and strategies were examined when working with familiar intensive quantities in which they had to compose a bigger or smaller amount of the same intensive quantity, given the intensive quantity in a bigger or smaller amount, respectively.

Children's preference for 'building up' strategies in the solution of proportional problems involving enlargement has been illustrated in many studies (Hart, 1988; Noelting, 1980; Piaget et al., 1968; Karplus, Pulos & Stage, 1983) which were limited to concentrating on extensive quantities. If a child is trying to find, for example, how many cans of blue paint there are in a total of 12 cans of light blue paint where the ratio of blue to white paint is 1: 2, then the child can reach the answer successfully by abstracting the relation between blue and white paint. In shrinking tasks, however, children cannot easily apply the same reasoning, because these problems do not provide the occasion for them to abstract the ratio involved;

the children need to discover the ratio themselves (Kaput & West, 1994). This may become even more complicated when intensive quantities are involved.

In this study enlargement and shrinking tasks were designed in which increasing and decreasing intensive quantities – more ordinary ones than some of those investigated before - were applicable. There were three main research questions: a) Are there differences in children's understanding of enlarging or shrinking intensive quantities and how does this understanding develop? b) Is children's ability to enlarge or shrink a part of an intensive quantity the same across different types of intensive quantities?, and c) Are there any age differences?

Method

Participants were 120 Greek children in the age range 8 to 10 years.

Half of the children answered the Enlargement Task and half answered the Shrinking Task; the distribution of children in each task was random.

The children were randomly half assigned to the Enlargement or Shrinking Task, with groups of children equally sampled from the three age groups.

In the Enlargement Task, children were asked to compose a larger amount of the same intensive quantity, given the intensive quantity in a smaller amount. For example, a given concentration of orange juice (1 bottle of orange concentrate and 2 bottles of water) was to be reproduced in a larger amount (to make 18 bottles of orange juice) all having the same concentration as the original sample. The Shrinking Task was parallel to the Enlargement Task, with the only difference that the children were asked to compose a smaller amount of the same intensive quantity, given the intensive quantity in a larger amount.

All the children were asked four questions which referred to mixtures of liquid (concentration of orange juice, concentration of paint) and distribution of money (for amount of sweets purchased, for amount of work done).

Results

a. *Comparison across tasks.* Children's performance was similar in both tasks (overall rates of success was 53% and 62% for the Enlargement and Shrinking Tasks, respectively), with their differences just missing significance ($\chi^2_{(4)}$=9.021, p=.061). The Shrinking task was more difficult than the Enlargement task only for the 9-year-olds ($\chi^2_{(3)}$=8.653, p<.05). Similar problem solving strategies across tasks were also found: the 8-year-olds mainly used incorrect intuitive strategies according to which they kept the relations involved in the right direction, but they did not consider the ratio invariant. The 9-year-olds calculated the ratio and employed a building-up strategy, whereas the 10-year-olds showed a preference for the calculation of the unit strategy. Statistical differentiation across tasks was observed with regards to the systematic use of their strategies: 90% and 100% of the 9- and 10-year-olds kept their strategies constant through all the problems in the

Enlargement Task, whereas about 50% of the same age group used the same reasoning in the Shrinking Task ($\chi^2_{(4)}$=12.390, p<.05).

b. *Comparison across types of intensive quantities*. Results in the Enlargement Task showed that children from all the age groups performed the same in the problems about mixtures and in the problems about money (z=-.351, p=.725). In the Shrinking Task, however, money problems were significantly easier than mixtures problems (z=-4.072, p<.001); this difference was significant for the 8- and 9-year-olds (p<.005 and p<.01, respectively) but not for the 10-year-olds who performed similarly in both types on intensive quantities.

c. Overall results showed significant *age effects* ($\chi^2_{(2)}$=14.524, p<.01). Separate analyses for each task revealed that age differences were found only in the Shrinking Task ($\chi^2_{(2)}$=12.668, p<.005); these were attributed to the 8-year-olds performing significantly worse than the 9- and 10-year-olds (p<.01) whose performance was similar (p=.341).

Conclusions

The results indicated that young children understand some underlying principles in increasing or decreasing an amount in intensive quantity. It is very possible that their choice between problem solving strategies might be related to their previous formal mathematics instruction – which is focused on extensive quantities - received at school. Thus, the need to further examine the variables that may contribute to the process of conceptual change in intensive quantities is suggested (emerges, is clearly stated).

No age differences in Enlargement - ?

Generally, and that schools are not taking full advantage of their mathematical understanding early on.

The eight-year-olds tended to believe that the parts that constitute the intensive quantity should be equal and only changed the total quantity according to the problem. Older children demonstrated more often an implicit notion that a relation exists between the parts in the intensive quantity in the given condition.

Using Symbolic Expression and Dynamic Manipulation to Construct Representations of Scale: The Perspective of Tool Characteristics in Facilitating Conceptual Change

Nikoleta Yiannoutsou, University of Athens, Greece

In the question what changes in conceptual change, Vosniadou et al (2001) advocate a qualitative difference in the knowledge structure organisation as opposed to a quantitative approach to conceptual change which is limited to the enrichment of the existing knowledge structure. Analysis of the factors facilitating conceptual change has focused on cognitive aspects -such as cognitive conflict (Vosniadou and Ioannides 1998) and on social interaction (including teachers' role, student collaboration and classroom orchestration Mason L (2001)). Little research has been done on the role the representational media play in formulating a learning environment (see Vosniadou et al 2001 for articulation of design principles) that fosters conceptual change.

Vygotksy (1934/1986) discussing the strong bond between language and thought argues that the representations individuals use -to express their thoughts- shape the way they are thinking and vise versa. Sherin (2001) has shown the influence of two different representational systems (algebra and programming language) in the intuitions students bring into learning the same physics concepts. Specifically his study revealed that students used a set of intuitions while working with algebra which was different from the set of intuitions the same students used while working with a programming language. Based on this theoretical background we conducted a study aiming to investigate the role of a representational medium that combines symbolic expression with direct manipulation in shaping students' conceptions about scale.

Research focusing on concepts of spatial cognition required for cartography and map reading identifies scale as one of the basic elements to understand maps. In most studies however, scale is studied solely as a method of establishing correspondence between space and its representations (Leinhardt et al 1998). We argue that this view overemphasizes the calculation methods that build a correspondence between space (or the initial model) and its representations placing little emphasis on the functional purpose of scale which is the maintenance of spatial relationships.

Traditional media (e.g. paper and pencil) can only support an approach to scale through the map – space correspondence (5 meters in space correspond to 5 mm on the map) but not through the spatial relationship approach we advocate here (Side "A" of the building is twice as big as side "B"). The reason is that traditional media cannot establish a dynamic relationship between the symbolic expression of spatial relationships and graphical output of those relationships. We therefore designed a computer-based learning environment, which combines symbolic expression with direct manipulation of the graphical output generated (by the symbolic expression). The programming language provided students with a vocabulary for articulation, reflection, refinement and communication of problem solving strategies and with means to focus on how things work (i.e. the mechanism underlying scale). Dynamic manipulation of the graphical output offered feedback for testing, evaluating and refining the symbolic expression of spatial relationships.

Students worked with the notion of scale in the context of a cartography activity that was implemented in four classes of fourteen year-old students. The activity was designed to facilitate inter- and intra – group collaboration and to trigger whole class discussions as context for negotiating spatial concepts involved in map construction. Specifically, pairs of groups engaged in joint construction of a computerized treasure hunt game and designed it so as to take place in their

campus. The game consisted of an electronic map of the area where the treasure hunt was going to take place, of a database with spatial information connected to the map and of clues placed in different locations in the area represented on the map. Students wondered around their campus and used a programming language (Logo in this case) to construct a dynamic model of the contours of the buildings based on their measurements. The idea behind the dynamic model was for the students to express symbolically the spatial relationships so that they could change the scale of their map through direct manipulation with the variation tool (for extended presentation of the software see Kynigos, 2002).

Our data collection was realised in real classroom settings through participant observation. Discourse analysis on students' dialogues indicated that coupling programming language with the use of the variation tool supported students in immersing into the mechanism of scale. Specifically, students' exchanges about the notion of scale seem to have shifted from a fragmented one to one correspondence between elements of space and elements of representation to a progressively holistic perspective that considers the relationship first between elements of the same object (i.e. building) and then between different objects. This shift appeared to be based on the visual effects provided by the direct manipulation facility of the tool and on the refinement of previous symbolic constructions. Our study indicates that the affordances of the tools used for the construction of representations of spatial concepts may play a crucial role in facilitating conceptual change. Since the type of tools used in a learning environment seems to be closely related to the concepts negotiated and the meanings generated, instructional research should address the learning process taking into account not only subject matter and activity design issues (such as teacher's – students' role, classroom orchestration etc) but also the characteristics of the representational media available.

References

Kynigos C. (2002). Generating Cultures for Mathematical Microworld Development in a Multi-Organisational Context. *Journal of Educational Computing Research, Baywood Publishing* Co. Inc. (1 and 2), 183-209.

Leinhardt, G., Stainton C. & Bausmith J.M. (1998) Constructing Maps Collaboratively; In *Journal of Geography* 97, 19 – 30 National Council for Geographic Education

Mason L (2001) Introducing talk and writing for conceptual change: a classroom study. In *Learning and Instruction* 11, 305 – 329

Sherin B. (2001) A comparison of programming languages and algebraic notation as expressive languages for Physics. In *International Journal of Computers for Mathematical Learning* 6, 1–61.

Vosniadou, S. & Ioannides, C. (1998). From conceptual change to science education: a psychological point of view. *International Journal of Science Education* 20, 1213-1230.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction*, 11, 381-419.

Vygotsky, L. (1986). *Thought and Language*. Cambridge, MA: MIT Press.

Using Tools and Constructing Identities: The Case of Two Gypsy Girls in School Arithmetic Practices

Anna Chronaki, University of Thessaly, Greece

There is currently an increasing awareness that the mathematics education of children who belong in minority groups is still a challenge at an international level. Apple (1995) argues that *'…the vast majority of schooling for the children of that 'lead-colored sea' –poor and working class students, girls and boys of color, and so many others – is not neutral, not in its means, and certainly not in its outcomes'* (p. 330). Mathematics, in particular, as a high-status knowledge domain in school, constructs a context where yet equity issues are either marginalized or completely missing in reform agendas or everyday pedagogic practice.

Predominant perspectives concerning the general poor performance of minority pupils have mainly focused attention on what individuals cannot achieve and assume that the problem resides in genetic, cognitive or cultural deficits. Instructional actions and educational policies are then geared towards changing pupils and their families so that to remedy the assumed imperfections. A different approach to the mathematical learning of minority children emphasizes the crucial role of classroom discourse in shaping and building their learning identities, acknowledges the distance between the social and cultural frames of reference of pupils and the ones implicit within the school, and attempts to use cultural diversity as resource considering seriously the contributions of ethnic minorities as a source of richness to be maintained and shared.

The present study adopts this latter perspective and studies the developing discourse between Giannoula and Maria (two young gypsy girls) and Sofia (an adult student teacher) on the basis of tasks and activities that produce a school arithmetic practice (e.g. problems concerning counting and arithmetic operations). The gypsy minority is a highly marginalized ethnic group (as compared to other ethnic minorities) with very distinct social and cultural characteristics (as compared to the dominant Greek culture). In contrast, to other minority groups (e.g. immigrants from Albania, or East European countries) that seem to be motivated in working hard to gaining entry and participation at school and community based practices, the gypsy children and their parents appear to be satisfied with learning the minimum of writing and arithmetic skills. Their participation in school is unsystematic, emotionally traumatic and can be described as an experience of continuous cultural conflicts. Although, some recent statistics concerning gypsy pupils' enrolment in school show an increase, the real numbers of pupils in schools

are still quite low. The aim of the study has been to explore what are the issues involved when the two gypsy girls attempt to enter the school arithmetic discourse and in particular how they use cultural tools and what is the nature of learning identities that the children are required to espouse in a supportive pedagogic environment.

The particular methodological steps followed in organizing this study were: *First,* the employment of an ethnographic methodology that enabled to establish trusting relations with the girls and their families. This experience of building relations was of vital importance not only for gathering the study data, but also for interpreting the meaning of data in the context they were produced (i.e. prolonged observation at home and school, interviewing and diary keeping). It was also important for establishing a supportive atmosphere for them to express themselves and their ideas.

Second, a set of arithmetic tasks were devised around the 'theme' of exploring the Euro (the new monetary unit in many European countries) which deal with basic number, counting, and arithmetic operations in problems of both an 'everyday purchasing' and an abstract nature. The type of tasks were related with; i) recognition and naming of the coins that represent divisions of the Euro, ii) searching for equivalences of a certain amount (e.g. in how many different ways can you produce the 1 Euro, the 50 lepta, the 80 lepta etc), and iii) problems which involved the purchasing of certain goods that the girls could buy in neighboring shops or markets (e.g. sweets, drinks, a dress etc).

And finally, the mathematical talk between Giannoula, Maria and Sofia was documented by tape-recording and transcribing the verbal interactions developing amongst them. The analysis was based on these transcribed interactions. The preliminary analysis of these data suggests that the mastery of mathematical learning of the ethnic minority girls develops not merely as mastering the use of 'school arithmetic tools' but at the same time as constructing 'learning identities' that enable them to position themselves in the practice of 'school mathematics'(Walkerdine, 1988). This double sided process is not developing in isolation but in a constant interaction with an adult who plays a quite direct and formative role. Further, these 'learning identities' can be realized in at least two dimensions a) as learning to value the using of cultural tools and b) as learning to be and behave in the particular practice of school arithmetic tasks.

References

Apple, M. 1995. 'Taking power seriously: New directions in equity in mathematics education and beyond'. In W. Secada, E. Fennema, L., B., Adajian (eds). *New Directions for Equity in Mathematics Education*. Cambridge University Press (pp. 329-349).

Chronaki, A. 2003. *Developing Mathematical Learning as Mastering Tools and Entering Discourses: some thoughts on a very complex process*. Paper presented at the EARLI Symposium 'The Social Mediation of Mathematical Learning in Multi-ethnic Schools' organized by Guida de Abreu. EARLI Conference. Padova. August 2003.

Chronaki, A. (2004, submitted). 'Entering the practice of school arithmetic: the experience of two young minority girls'. In *European Journal of Educational Psychology* [special issue edited by Guida de Abreu and Ed Elbers: The Social Mediation of Learning in Multi-Ethnic Schools].

Sfard, A (2001). Cognition as communication: Rethinking learning-by-talking through multi-faceted analysis of students' mathematical interactions.

Walkerdine, V. (1988). The Mastery of Reason: Cognitive development and the production of rationality. Routledge. London.

Combining different Mental Representations on Conceptual Change in Mathematics - the Case of an Identity

Panagiotis Delikanlis and Petros Verikios, University of Athens, Greece

In this study we examine the meaning of representations in teaching and understanding mathematical concepts. An instructional approach of concept of a mathematical identity and its proof is based on:

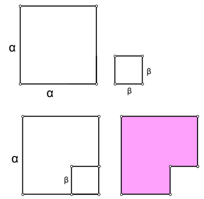
The consideration of the three types of mental representation: propositional representations which are strings of symbols that correspond to natural language, mental models which are structural analogues of the world, and images which are the perceptual correlates of models from a particular point of view (Johnson-Laird, 1983).

- How do mental models influence the learning that takes place in a domain? It is important to distinguish two kinds of learning- learning that enriches the prior knowledge that already exists in the knowledge base, and learning that requires the restructuring of this knowledge. It is assumed that in most cases the process of knowledge acquisition is one that involves the enrichment or articulation of existing knowledge structures. Occasionally, when students are faced with major anomalies that their existing conceptual structures cannot account for, a new structure is required. (Vosniadou S., 1992). For example proof of identities. We look at the algebraic knowledge that already exists for the derivation the proof of identities.
- Visualization plays an essential role in the work of many eminent mathematicians. Visualizing is one process by which mental representations can come into being. (Kaput 1987b); according to this theory, the act of generating a mental representation, relies on a representation system, i.e. concrete, external artefact algebraic formulas, arrow diagrams and value tables .

Research of cognitive psychology (Vosniadou S., 2001) gives us basic principles of learning as:

- Active involvement
- Social participation
- Meaningful activities
- Relating new information to prior knowledge
- Helping students learn to transfer

The goal of this study is to give students a chance to move from prepositional representation, given mathematical identities, to image representation. A proper method to achieve the above-mentioned goal is to find an image representation. A geometrical model is an image representation. Gagatsis and Patronis (1990) define a geometrical model as follows: A collection S of points, lines or other figures in n-dimensional Euclidean space, representing a system *Σ* of objects or a situation or process, is a (theoretical) *geometrical mode of Σ,* if the intrinsic geometric properties of the elements of S are all relevant in this representation, i.e. they correspond to properties of the system *Σ.* If this condition is satisfied only for the *topological* properties of lines or figures in S, we shall speak about a *geometrical model in the wide (or topological) sense.*



The following example is meant for students of 14-16 years old. Let us consider identity $\alpha^2-\beta^2= (\alpha+\beta)(\alpha-\beta)$, a propositional representation. A simple form of image representation of the first member, $\alpha^2-\beta^2$, is the shape which is called gnomon (coloured figure). The small square, side β, in the bigger one, side α, gives a common image schema, the Container schema . (Lakoff, G. and Nunez, R:, 2000) which allows us to make the conceptual change using a spatial relation concept.

Our study is an instructional approach which has not yet been applied in the classroom. Its application in the classroom will be the next phase. The elaboration of the results of such an application in the classroom will complete our study.

References

Johnson-Laird, P.N. (1983). *Mental Models* (Cambridge: Cambridge University Press)

Gagatsis, A., & Patronis, T. (1990). Using geometrical models in a process of reflective thinking in learning and teaching mathematis. *Educational Studies in Mathematics*, 21 (3), 29-54.

Kaput J. J. (1987b). 'PME 11 Algebra papers: A Representational Framework', *Proceedings of PME11,* Montreal, 1, 345-354.

Lakoff, G. and Nunez, R., (2000) Where Mathematics Comes From: How the Embodied Mind Creates Mathematics.

Vosniadou S. (2001). *How People Learn.* Intemational Academy of Education. (http://www.ibe.unesco.org).

Vosniadou S.(1992). Knowledge Acquisition and Conceptual Change. *Applied Psychology: An International Review*,41 (4) 347-357

B. Conceptual Change in Physics

Chair: Chair: Panagiotis Kokkotas, University of Athens, Greece

Discussant: Dimitrios Psyllos, Aristotle University of Thessaloniki, Greece

Development of Students' Representational Coherence

Jouni Viiri*, University of Joensuu, and Antti Savinainen, Kuopion Lyseo High School, Finland

This study is concerned with students' conceptual development in mechanics. Conceptual development is characterized through analysis of the development of representational coherence. A method for evaluating high school students' representational coherence is presented and the results discussed.

Introduction

Many studies show that students frequently do not use multiple representations such as texts, pictures or graphs effectively, and that they have difficulty moving across or connecting multiple representations (van Someren et al. 1998). It has, however, also been shown that the ability to use more than one representation deepens a student's understanding (Kozma 2003).

A student's ability to use multiple representations correctly and to move between them indicates the representational coherence of the individual student's understanding. Representations include verbal (written and oral), diagrammatic (vectors, motion maps, path diagrams) and graphical (e.g. velocity against time graphs) representations. Representational coherence has, therefore, been included in our characterization of students' conceptual coherence (Savinainen &Viiri 2003a).

The development of conceptual coherence could be taken as one measure of the conceptual development. Duit (2003) he concludes that "most studies show that the old ideas stay alive in particular contexts." Our aim in this paper is to show that, in addition to context, the development of students' understanding also depends on representation. In the present case-study we investigate only the various representations of Newton's second law, although it should be noted that in Savinainen & Viiri (2003b) we described our method of probing and analyzing representational coherence in greater detail.

Data gathering and analysis

A study was made of the representational coherence of five case study students (aged 16) taking an introductory high school mechanics course taught by the author AS.

Data was collected by means both of multiple choice tests and of interviews to permit methodological triangulation. Since interviews provided more direct data on the students' representational coherence, in this paper we will discuss only the results that are related to the interviews. The pre-interview was administered just after introducing the force concept and the delayed interview 1.5 months after the conclusion of the course. The five students were chosen for interview on the basis of their success in the pretest. The interview questions were designed to address the students' ability to move between different representations.

The students' results were placed in three categories:

I	'incorrect'	essentially incorrect answer(s)
II	'partially correct'	partially correct answers or explanations
III	'correct'	correct answers and explanations

A student exhibits representational coherence if he/she reaches category III in all of the questions within the different representations. The students' responses were analyzed separately by both authors in order to obtain investigator triangulation.

Results

The results from the different representations of Newton's second law are presented in Figure 1.

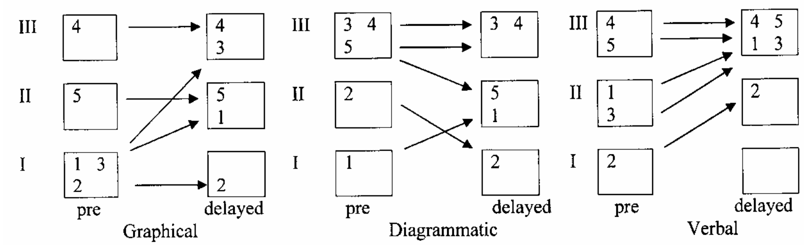


Figure 1. Distribution of the students (1, 2, 3, 4, 5) into the categories of different representations.

In general, the students seem to have done better in the delayed interview than in the pre-interview. They developed more in the verbal representations than in the other types. This suggests a partial stable development of representational coherence. Looking at the individual students' development, we see that Student 4 already exhibited representational coherence in the pre-interview. Student 1 developed in all of the representations, while Student 3 did so in the verbal and graphic representations. Student 2 made progress in the verbal representation but experienced negative development in the diagrammatic representation. Student 5 development was negative, since in both the graphic and the verbal representations he remained within the same category, while in the diagrammatic category his development was negative.

Discussion

The method developed for studying representational coherence seems effective in revealing students' strengths and weaknesses, and the categorization and representation could also be useful in mapping the development of students' conceptual coherence in other areas of science.

Students' understanding of physics tends to be context-dependent (e.g. Palmer 1997). Duit (2003) also points out, that studies of students' conceptual progress show that their old ideas remain alive in particular contexts. The interview data related to Newton's second law suggests that students' understanding also depends on representation. To minimize the effects of context, all of the interview tasks in this study were presented within one context at a time.

The present case study lends further support to the idea that conceptual development is in fact a partial evolution. Students' conceptions develop in different ways, depending on the representation studied. This tends to support the statement made by Schotz et al. (1999) to the effect that "instead of being replaced, the naïve conceptions frequently stay alive and co-exist besides the new conceptions." Vosniadou and Ioannides (1998) also claim that learning science should be viewed as a gradual process during which initial conceptual structures are continuously changed. In this study it was found that there was some development, but not a general revolution, in conceptual change. This is indicated by the various different changes in the different representations.

References

Duit R. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *IJSE* 25 (6), 671–688.

Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction* 13, 205-226.

Palmer, D. (1997). The effect of context on students' reasoning about forces, *International Journal of Science Education*, 6, 681-696

Savinainen, A. & Viiri, J. (2003a). Using the Force Concept Inventory to characterise students' conceptual coherence. In L. Haapasalo & K. Sormunen (eds.) *Towards meaningful mathematics and science education.* University of Joensuu, Bulletins of the faculty of education. 142-152.

Savinainen, A. & Viiri, J. (2003b). A case study on evaluating students' representational coherence of Newton's first and second laws. AAPT PERC conference, Wisconsin. http://perlnet.umephy.maine.edu/perc2003/abstractsroundtable.htm

Schotz, W., et al. (eds.) (1999). *New perspectives on conceptual change*. Elsevier: Oxford.

van Someren, M.W., et al. (Eds.) (1998). *Learning with multiple representations*. Oxford: Elsevier.

Vosniadou, S. & Ioannides, C. (1998). From conceptual change to science education: a psychological point of view. *IJSE* 20, 1213-1230.

The Construction of Concepts of Electricity by Students of 11-17 Years Old

Martha Koutsiouba-Peonidis, Higher School of Pedagogical and Technological Education, Thessaloniki, Greece

It is widely known from research concerning the teaching of physics that primary and secondary education students do not understand the scientific definitions of basic concepts of electricity (voltage, electric current, resistance and electric power) not only before but, at a significant percentage, after instruction. Alternatively, they prefer to use the more familiar concepts of 'force' or 'energy' as synonymous with the above electricity concepts. However, there are only a few studies that try to connect alternative ideas with student age and to keep track of the developmental course of the construction of the scientific meaning of electricity concepts.

In this study I investigate empirically the conceptual change that takes place in the construction of concepts of electricity at school age. My aim here is to set up a developmental system for the analysis of the alternative ideas of students with respect to voltage, electric current, resistance and electric power and then to test its validity against students from 11 to 17.

In the first part of this study I survey the literature concerning the different ways students understand the foregoing concepts of electricity. For instance, when students are asked about the meaning of voltage they answer that it is a battery 'energy' or a property of the current which indicates its 'strength', 'force', or 'power'. In addition students understand the concept of current as 'burning fuel', as a fluid that is contained in the battery, as well as 'energy'. I offer a detailed analysis of the students' ideas and the conclusions I draw are as follows: (a) Sometimes, the meanings of the foregoing concepts are organized at a macroscopic level on the basis of phenomenological experience, while some other times they are organized around microcosmic entities that are involved in models of learning experience. (b) The concepts of 'power' and 'energy' are basic components of the investigated meanings. (c) The reasoning students employ is linear and causal. Here the concepts of electricity constitute, among others, the cause of change either of intensity or duration of the brightness of the bulb.

The foregoing components of students' ideas are examined from a developmental point of view. In particular:

Studies on the categorization of natural concepts mention the existence of a basic level along which concepts share many perceptual and functional qualities. Moreover, they point out that an early stage in the acquisition of natural concepts is related to perceptual experience. From these we assume that when it comes to the organization of physics concepts there is a prior level in their approach in which they enjoy a high level of generality. This means that they explain a broad category of phenomena, that they derive from experience and that they are associated with objects surrounding us (macrocosm).

Other studies maintain that language constitutes a basic means for concept construction in general, but it has been found out that particularly in physics it can be a source of misconceptions. In the context of language contribution, we focus on the use of force and energy since they are among the most widely used concepts in physics and in ordinary life. It has been found out that in comparison to energy, force is observed earlier in Greek children's vocabulary. The former appears to be detached from the context of learning experience and to penetrate in the everyday life context (Koumaras & Koutsiouba, 1999).

From a comparison of students' reasoning that refer to changes in the intensity of a phenomenon with their reasoning concerning changes in duration, I infer that the two sorts of reasoning differ (a) in the time of occurrence and (b) in the preservation of a situation. The intensity of a phenomenon involves the description of the situation in the present, while its duration involves its continuation in time. According to Piaget the introduction of time in reasoning and the notion of preservation are late achievements of thought. Finally, it has been found that students relate 'force' to the intensity of a phenomenon and 'energy' to its duration (Koumaras & Koutsiouba, 1999). All these have led us to the conclusion that reasoning about the intensity of a phenomenon precedes, in a developmental sense, reasoning about duration.

With the above analysis I constructed a general theoretical framework for the hierarchical organization of students' ideas in developmental levels. In particular, the concepts of electricity can be organized in two levels in addition to the scientific model which forms a third level. According to this division it is possible that:

- the construction of electricity concepts has as a starting point that includes objects of the sensible word, the concept of force and co-variations that occur only in the present, while the relevant reasoning refers to the intensity of the phenomenon. And
- there are more sophisticated types of representation to which belong elements of the microcosm and the concept of energy, while the relevant reasoning refers to the duration of the phenomenon.

To test this systematic analysis I conducted empirical research. The sample consisted of 433 elementary and secondary education students of the age of 11, 13, 15 and 17 years old. They were asked to answer in writing close questions about what each concept of electricity exactly meant. Answers were analyzed by the Hierarchical Cluster Analysis method. Four types of representation were specified corresponding to each one of the basic concepts of electricity which are phases of a developmental sequence. According to our findings acquired through

the x^2 test (adjusted standardized residuals) representations of students up to 13 years old are associated basically with the phenomenological level, but there is a progressive decrease in the older students. Whereas from the age 15 and on more refined types are observed. The scientific model is observed even in younger students due to the influence of instruction, but the percentage is increased progressively as we move to older students.

The Use of Knowledge about Floatation in Different Contexts: A Situated Approach of the Model of Conceptual Change

Mario Carretero, Maria Rodriguez Moneo, Universidad Autónoma de Madrid, Spain

Taking situated models of conceptual change as a reference, the role of acquisition and the use of knowledge are considered to be of fundamental importance (see for recent reviews, Limon and Mason, 2002 and Schnotz, Vosniadou and Carretero, 1999).

In general, conceptual change is not regarded as the substitution of some conceptions for others but as context discrimination and the right use of conceptions in each context (Carretero, 2000, Linder, 1993, Halldén, 1999).

From this perspective, we can explain the coexistence of both alternative and scientific conceptions in the same context (Aparicio y Rodríguez Moneo, 2000). In this piece of research we intended to verify this point and to analyse subjects' answers in different contexts.

We carried out the research with two groups. One of them consisted of 23 graduates in Philology (novices) and the other one of 26 graduates in Physics and Chemistry (experts). All of them were following a postgraduate course on Initial Teacher Training at the Autónoma University of Madrid which included lectures on Specific Methodology and Didactics which would, in a near future, enable them to become secondary teachers.

All the subjects were required to complete a test on single manipulation which had different parts. The first one aimed at fixing their expertise level. The main purpose was to find out their initial conceptions on floating, area of knowledge related to Physics. The second part tried to test how novices and experts behaved in an ordinary teaching context. In order to do so, two questions on Physics were asked. The first one referred to an "ordinary teaching context" and it was about how the subject would teach a group of youngsters to predict floating. Those youngsters were the same age group the trainee would have to teach in the future. The second question referred to "self behaviour in everyday context" and the subject was asked how he/she would predict the idea of floating. There was a third and last question in the research and it was on how the subject would behave in an academic context. This last part was similar to the previous ones. It only deferred in the context. Two similar questions were asked but, in this case, in an academic context ("teaching in an academic context" and "self behaviour in an academic context").

The analysis categories which enabled to identify how the subjects explained the different questions were prepared following the classification used in other studies (Baillo y Carretero, 1996, Howe et al. 1990, Smith et al., 1992, Rodriguez Moneo, 1998).

The results showed the following:

a) Novices' conceptions on floating were indeed more basic than experts' conceptions. Novices explained the idea of floating using weight as a reference and experts did it by comparing densities. As in other studies, it was clear that the notion of weight precedes that of density. (Baillo y Carretero, 1996, Rodríguez Moneo, 1998, Smith, et al., 1992).

b) In all the questions asked in the different contexts, there were significant differences between novices' and experts' conceptions. Novices always used more basic conceptions than experts.

c) Basically, novices taught, in an everyday and academic context, following the same methodology. In both contexts, novices based their explanation on weight when trying to predict buoyancy.

d) However, there were significant differences when experts taught in different contexts. In an everyday context, experts based their explanation on weight. That is to say, they simplified the theoretical level and used alternative conceptions in an everyday context. Yet, the theoretical level increased when in an academic context and they mainly focused on comparing densities.

e) there were significant differences between the everyday and academic contexts. The most important ones being when experts used alternative conceptions based on weight and the absolute density of objects in an everyday context and on the contrary, they used scientific comparison of densities in an academic context.

References

Aparicio, J. y Rodríguez Moneo, M. (2000). Los estudios sobre el cambio conceptual y las aportaciones de la psicología del aprendizaje. *Tarbiya, 26,* 13-30.

Baillo, M. y Carretero, M. (1996). Desarrollo del razonamiento y cambio conceptual en la comprensión e la flotación. En M. Carretero (Ed.) *Construir y enseñar las ciencias experimentales.* Buenos Aires: Aique.

Carretero, M. (2000). Cambio conceptual y enseñanza de la historia. *Tarbiya, 26,* 73-82.

Halldén, O. (1999). Conceptual change and contextualization. En W. Schnotz, S. Vosniadou y M. Carretero (Eds.) *New perspectives on conceptual change.* Oxford: Pergamon.

Howe, C, Tolmie, A. y Rodgers, C. (1990). Physics in the primary school: Peer interaction and the understanding of floating and sinking. *European Journal of Psychology Education, 4,* 459-475.

Limon, M. & Mason, L. (eds.) (2002) *Reconsidering Conceptual Change.* Kluwer

Linder, C. (1993). A Challenge to conceptual change*. Science Education, 77,* 293-300.

Rodríguez Moneo, M. (1998). *Las concepciones alternativas y el proceso de cambio conceptual*. Madrid: Universidad Autónoma de Madrid.

Rodríguez Moneo, M. (1999). *Conocimiento previo y cambio conceptual.* Buenos Aires: Aique.

Smith, C., Snir, J. y Grosslight, L. (1992). Using conceptual models to facilitate conceptual change: The case of weight-density differentiation. *Cognition and Instruction, 9,* 221-283.

Schnotz, W., Vosniadou, S. & Carretero, M. (eds.) *New perspectives on conceptual change.* Amsterdam: Elsevier.

Conceptual Mediation (CM): A New Theory and a New Method of Conceptual Change in Practice

Harry Lyndon, Department of Education and Children's Services, Government of South Australia

This paper presents an overview of a new theory and a new method of conceptual change and reports on their practical application in the mediation by students of conflicting concepts in science education. The term, mediation, is here used to mean that an individual consciously attempts to reconcile his or her conflicting concepts. The theoretical perspective proposes that the well-documented learning difficulties experienced by science students arise as an outcome of the natural tendency of the mind to conserve prior learning in the face of conflicting new experience. It is argued that this tendency is a universal attribute of human cognitive development caused by the associated phenomena of proactive inhibition and accelerated forgetting.

It has been shown that where students and their teachers apply CM strategies in a collaborative way that student's learning of counter-intuitive concepts and skills is significantly increased compared to that of students using conventional learning strategies. CM students achieved significantly higher tertiary entrance scores (an effect size of 1.04) and the program worked equally well for both genders. Further beneficial outcomes of this program are significant improvements in student behaviour, positive attitudes toward school, time on task, and improved self-esteem, particularly in male students. Detailed results of evaluations of the CM program's influence at two Australian public secondary schools will be presented.

Consistency versus Fragmentation in Mechanics"

Thanasis Mol, Christina Stathopoulou and Stella Vosniadou, University of Athens, Greece

There is much empirical evidence showing that students hold ideas about force and motion that are not compatible with the Newtonian theory of motion. (e.g. Clement 1982; McCloskey, 1983;Viennot, 1979; diSessa, 1988, 1993; Vosniadou & Ioannides, 2002) Nevertheless, researchers disagree on how to interpret the empirical findings. Some argue that students have misconceptions in dynamics (such as the 'impetus' misconception) representing well-formed alternative theories that need to be properly replaced in the process of learning science. (e.g. McCloskey, 1983; Posner, Strike, Hewson & Gertzog, 1982). Others argue that students' naïve ideas, regarding dynamics, comprise a collection of a large number (hundreds or thousands) of intuitive knowledge elements which in the form of explanatory primitives are activated in specific contexts, but individually or as a whole are not systematic enough to be assigned a theoretical character (diSessa, 1988,1993). Still a third position is that students' misconceptions are "synthetic models", i.e. attempts to synthesize the scientific views with a naïve framework theory of physics, which is constructed in early childhood and consists of certain entrenched presuppositions. Such a presupposition is that force is a property of objects (Vosniadou 1994; Ioannides & Vosniadou 2002).

The present study seeks to present additional evidence in support of this third position, stemming from research, which used the FMCE (Force and Motion Conceptual Evaluation). This is a multiple choice assessment instrument, designed at the Center for Science and Mathematics Teaching, at the Tufts University to probe high school, college and university students' conceptual understanding in Newtonian mechanics (Thornton & Sokoloff, 1998). Students' understanding of Newton's first and second laws was probed by questions of different types, with the students having to choose among 7-9 given answers per question represented verbally or as graphs.

The research was conducted in two phases. In the first phase, a total of 60 tenth-grade high school students and 74 physics students, all freshmen, were administered the FMCE. The second phase followed six months later, after making sure that all participating students had been exposed in instruction concerning Dynamics. In the second phase the same 60 high school students and 88 physics students, among them the majority of those that took part in the first phase, were again administered the FMCE.

In this study we present results from the analysis of nine FMCE items: those that directly investigate the conceptual understanding of Newton's first and second law, regarding one-dimensional, translational motion. Three of the items refer to situations explained by the first law, whereas the remaining six items refer either to speeding up objects (three items) or to slowing down objects (three items). Some items involve choice among verbal alternative answers, describing explicitly the force acting on a sled moving on ice, without, however, reference to the coordinate system. The remaining items have alternative force-time graph answers describing implicitly the force acting on a toy-cart that moves on a given coordinate system. Consistency in the use of a certain meaning of force was investigated through examining the frequency distribution of all possible triplets of students' answers. The results showed that the majority of both high school and university students' responses (about 70% in each case, before and after instruction) could be grouped in a small number of triplets of answers (seven, or less, in each case, before and after instruction) that, apart from the scientifically accepted, may be considered as representing 'synthetic models'.

References

Clement, J. (1982). Students' Preconceptions in Introductory Mechanics. *American Journal of Physics*, 50(1), 66-71

diSessa, A.A. (1988). Knowledge in Pieces. In G. Forman & P.B. Putfall (Eds.) *Construvtivism in the computer age* (pp.49-70). Mahwah, NJ: Erlbaum.

diSessa, A.A. (1993). Toward an Epistemology of Physics. *Cognition and Instruction*, *10*, 105-225

Ioannides, C., & Vosniadou, S. (2002). Exploring the Changing Meanings of Force: From Coherence to Fragmentation. *Cognitive Science Quarterly*, 2(1), 5-61.

McCloskey, M. (1983). Naive Theories of Motion. In D. Gentner & A.L. Stevens (Eds.) *Mental Meanings*. Mahwah, NJ: Earlbaum

Posner, G.J., Strike, K.A., Hewson, P.W. and Gertzog, W.A. (1982). Accommodation of a Scientific Conception. Toward a Theory of Conceptual Change. *Science Education*, *66* (2), 211-227

Thornton, R.K., & Sokoloff, D.R.(1998). Assessing Student Learning of Newton's Laws: The Force and Motion Conceptual Evaluation and the Evaluation of Active Learning Laboratory and Lecture curricula. *American Journal of Physics*, *66* (4), 338-352.

Viennot, L. (1979). Spontaneous Reasoning in Elementary Dynamics. *European Journal of Science Education*, *1* (2), 205-225

Vosniadou, S. (1994). Capturing and Modeling the Process of Conceptual Change. *Learning and Instruction*, *4*, 45-69.

C. Conceptual, Epistemological and Educational Approaches and Changes at the Technical Professional Educational

Organizers: Andronikos E. Filios and Ourania Kalouri, School of Pedagogical and Technological Education, Greece

Chair: Leonidas Gomatos, School of Pedagogical and Technological Education, Greece

Discussants: Anastasia Athanasoula-Reppa, School of Pedagogical and Technological Education, Greece
Panos Polychronopoulos, University of Patras, Greece

Historical and Conceptual Evolution of Technical - Vocational Education

Maria Kantonidou-Daskalaki*, Anastasia Athanasoula-Reppa and Maria Koulianou, School of Pedagogical and Technological Education, Greece

The aim of this paper is to help provide a better understanding of the conceptual evolution of *Technical-Vocational Education (TEE)* by placing the term in historical context. This is because the failures and successes of TEE in Greece, as in any other country, can only be perceived from the historical and socio-political context of education in the region. Our working hypothesis, grounded in the doctrines of Pragmaticism, is that at different times a term acquires different meanings and involves different historical references that reflect the particular socio-political and ideological conditions on which the education-society rapport rests.

To achieve the above aim, a historic-comparative approach, re-citing, rather than citing, and/or engaging authentic sources (laws, reports of national and international organizations, parliament minutes, etc) has been adopted. The approach has been to select these sources with due regard for the way they are directly related to the contextual setting signaling the emergence of the term's new meaning or the broadening of the existing one. Evidently, TEE is not a level of education growing in isolation; nor is it a sector of an educational system undergoing structural reforms and semantic changes in a vacuum. TEE is the point where societal and educational demands intersect and where national policies should interact with international trends. Given the complexity of this realization, our undertaking is anything but easy.

Generally speaking, views and opinions on the semantics and dynamics of TEE date back to arguments about the precedence of brain work over manual work and the concomitant prevalence of General Education which eventually led to the marginalization of TEE. They also relate to arguments about class-conscious distribution(s) of labour (white collar vs blue collar jobs/workers), and to notions

reflecting the structural and societal features of each era, as is the case with the public vs the private sector schema.

The study sets out to clarify the conceptual framework of the term's making. The origins of TEE can be found dating back to *ancient times* (Ancient Greece & Rome). Although back then the term did not really exist, the seeds from which technical education grew, first as a notion and then as a term, did exist: one can easily trace them in the apprenticeship scheme employed in by Ancient Greeks and Romans and outside the family. One can also trace the sheer ideological depreciation of manual work intended for the "brute" and the "unrefined", i.e. for people of no spiritual interests, whose actions and activities involved no thought or reason. The study, then, seeks to interpret the slight change in attitude discerned in the *Byzantine era.* The precedence of prayer over philosophical meditation could have helped the Byzantines realize the value(s) of manual work and of those that performed it. It did not. What it did, was to help them realize and/or recognize its necessity.

A concise account of the *pre-industrial period* follows, the focal point being the education and the professional training of young people, which is now the responsibility of the family: children are literally sent to serve periods of apprenticeships with skilled masters either in their own household or within the framework of an elementary boarding scheme. The study then focuses on the major socio-political changes recorded in the second half of the 18th and throughout the 19th century (making of the state, industrial revolution, technological transformation), and the impact they had on policies concerning education. Arguably, every citizen was entitled to education – a potentiality which a century later became a social right, the exercise of which was guaranteed by the state.

The end of the industrial revolution signals the "massification" of education and the emergence of the need to lay particular emphasis on vocational training so as to produce specialized technicians at the level of Secondary Education. That meant organizing and developing a system of Technical and Vocational Education within both the public and the private sector. It was a worth-while effort which started to gradually shape up and be systematized until it led to the integration of TEE into the formal education system. It was through this integration and systematization process that the conceptual boundaries of TEE expanded and broadened to include the notions of "professional skills" and "professional training", seen against the background of the lifelong learning vision and mission of today's society. The conceptual boundaries of the term, however, were bound to expand even further. The radical changes in the wake of the information society, along with the rapid development in information technology and the fighting of technological illiteracy, freed the term from the limitations of the word "technical" by giving the acronym (TEE) an additional meaning: nowadays T stands for technical, as well as for technological.

In an attempt to recapsulate the afore mentioned arguments, we end our historic and comparative search of the conceptual evolution of TEE, by engaging extracts from a number of authentic sources (OOSA, Treaty of Maastricht, etc). The working hypothesis is thus revisited and substantiated through and from a different perspective: that of the organization of TEE in various European countries, including our own. In Greece, the transition from the old Technical Vocational Schools (TES) to the present ones (TEE) and from the General Lyceum to the Lyceum of the Unified Sector (reformed to include the technological dimension, as well), reflects the agonizing process of TEE towards its conceptual identity and due recognition.

Is Technology an Autonomous Kind of Knowledge? Implications of the Issue in Technology Teaching

Leonidas Gomatos, School of Pedagogical and Technological Education, Greece

Technology Education is looking for an identity. Neither Science Education nor manipulation of equipments and devices are enough to describe what Technology Education is, although they are both in close relation with it. Our hypothesis is that this question is directly related to the question of the "nature" of Technology or else to the status of Technological Knowledge.

Philosophers such as Heidegger, Marcuse and Habermas presented considerable work on the theme of Technology. Along with other philosophers they contributed to the emergence of Philosophy of Technology as a separate philosophical theme, which is maybe less extended than the close branch of Philosophy of Science. Among the questions posed is whether Technology is an autonomous kind of Knowledge or it is an application of sciences such as Physics, Chemistry, Geology, Biology etc.

Works in History of Science, show that Technology cannot be considered as an application of Science. The path may sometimes be in the opposite direction. The questions that pose some real situations, some "technological themes", often lead to scientific investigations. Two examples are discussed in this work.

The technological problem presented to Galileo in 1638 by an Italian farmer (*Water could not be pumped from the wells*) led to the introduction by Torricelli, some years later, of the concept of atmospheric pressure as well as to the famous experiments of Pascal on atmospheric pressure.

Watt's improvements on Newcomen's steam pump had been put in practice many decades before the introduction of Thermodynamics' second law. Technological practices on the theme have certainly much contributed to scientific investigations.

The purpose of this study is not to contribute to theoretical investigations on the question of the status of Technological Knowledge but to approach Technology teachers' representations of this status. Furthermore, the interrelation between

these representations and educational choices and practices is part of our investigation. Teachers' representations of what Technological Knowledge is may influence Technology teaching. The selection of themes in the curricula, schoolbooks and teaching material as well as technology teachers' everyday practices may be determined to a certain degree by those representations.

School technology courses, in Greek high schools, resemble either to science courses or to apprenticeship. Identity of Technology Education does not seem to be established. Reasons such as the following can be proposed as an explanation and they are discussed in our work.

- Lack of tradition in technology teaching may play a role. If a subject has little or no tradition in school teaching, then loans from other subjects are necessary. In the case of Technology Education, those loans come from Science Education. This may explain for instance, the presence of so many closed problems in technology schoolbooks, whereas social and professional practices of reference are characterized by open-ended problems.
- Interrelation between school and labor market is weak. This leads, among other things, to a lack of task analysis from an educational point of view. Thus, critical actions of technological task that could give ideas of educational objectives do not come to the surface.

We would like to see through our work if teachers' representations on the status of Technological Knowledge could be added to those reasons.

Three problem situations presenting different characteristics are proposed to teachers of technological subjects in secondary schools. The problems could possibly be used as a work material in class. Teachers' task is to characterize problems and evaluate their utility as tools of classroom work. An interview follows with each teacher. The questions focus on the cognitive demands of each problem, on eventual strategies of pupils and on the degree that teachers consider each situation as a "technological theme". Moreover, teachers' representations concerning the status of Technological Knowledge are approached during the interviews.

Analysis shows that specific aspects of the problems favor their characterization by teachers as "technological themes". Teachers' characterizations are interrelated with their respective representations of the status of Technological Knowledge.

The Educational Formation of the Graduates as a Change of Conceptual Orientation

Maria Vaina* and Irene Petsimeri, School of Pedagogical and Technological Education, Greece

The purpose of this paper is to bring to the front part the intense mental procedure of higher education graduates, when they are enrolled in programmes of educational formation, in order to acquire the identity of the educator. The paper also aims, by clarifying this procedure, at contributing to the improvement of the quality of the given educational formation.

The methodology used for this double purpose is *hermeneutics*, as far as the theoretical part is concerned, and a small-scale *empiric research*, extracting results by using the relevant questionnaire. The *comparative method*, finally, will contribute to the comparison of the theoretical and empirical results.

The "conceptual universe" of the higher education graduates insures the necessary coherence and consistency in a world of specialization. The process of educational formation broadens the mental horizon. The contents of the educational formation programme, complementing each other, literally invade a mature person's way of thinking, causing a powerful dynamics in terms of conception. New key-terms signify the new field of knowledge. In this paper, representative theoretical schemes of the above mentioned dynamics will be defined and interpreted; what will also be interpreted are the major phases, through which a higher education graduate undergoes, until the completion of his educational formation according to the paradigm of the one-year taught programme of educational studies in the School of Pedagogical and Technological Education, Greece.

The systematic broadening of the conceptual horizon towards the direction of Education –a purely cognitive phenomenon– also works as a moral phenomenon of the "educational thinking and doing". The science of education rises up as a common "teaching cover" of different sciences and vice versa: each science is re-defined under the light of education.

Application of Multiple Intelligence Theories in the Teaching and Learning of Technological Courses

Andreas Oikonomou, School of Pedagogical and Technological Education, Greece

The conventional ideas for the school success not taking into consideration the Multiple Intelligence (MI), they misunderstand the particular talents of the students. Most teachers pay excessive accent in reason intelligence comparatively to all other forms of intelligence. So, a lot of students that do not allocate this preferential intelligence lose their interest for the school and important percentage from them abandon. The aim of this presentation is concisely to present basic elements of MI theories, to propose applications in the Greek educational system, supporting that this will particularly have a lot of positive consequences in the Technological Education. In this proposal is included also the introduction of teaching of MI in the Bachelor Programs and the Annual Pedagogic Programs of the Teachers Training in the School of Pedagogical and Technological Education which mainly prepare the future teachers of technological courses.

Two theories for multiple intelligence

a. The theory of Gardner

The basic idea of the Gardner theory for the MI is to extend the traditional perception for the intelligence. Appreciating that the conventional scales of measurement of intelligence examine mainly linguistic and reason intelligence, the Gardner underlines that the intelligence should be faced as a wider spectrum. After years of studies, he has been determined a total of eight different dimensions of intelligence:

- Linguistic intelligence (poet, philologist)
- Logico-mathematical intelligence (positive scientist)
- Spatial intelligence (technician, seaman, surgeon)
- Musical intelligence (musician)
- Bodily-kinesthetic intelligence (dancer, athlete, artist)
- Interpersonal intelligence (comprehension and motivation of other persons, collaboration)
- Intrapersonal intelligence (self-concept and self-knowledge)
- Emotional intelligence (comprehension of our own sentiments, comprehension of sentiments of the other and their management in a advantageous way for all)

The dimensions of intelligence could become comprehensible not as constant faculties, but rather as crude possibilities that could be developed through suitable training activities. For schools and teaching, consequently, the main aim should be the growth of MI and the students to be strengthened so that they achieve the corresponding objectives suitable for the particular spectrum of their intelligence. Gardner proposes a school that is mainly based on two basic fundaments:

- All the people do not have the same interests and the same possibilities. All do not learn with the same way.
- An individual cannot learn all these which are proposed to him for learning.

b. The theory of Demetriou

Demetriou, in the last version of his theory, supports that in the intelligence exists five dimensions:

1. Categorical reasoning. The categorical reasoning enables the person to identify information that is important for the task at hand and reduce unnecessary complexity so as to facilitate future information selection needs. Thus, categorical reasoning specializes in the handling of similarities and differences between objects.

2. Quantitative reasoning. All elements of reality can potentially undergo quantitative transformations. Things aggregate or separate so that they increase, decrease, split, or multiply in space or time for many different reasons.

3. Spatial reasoning. Spatial reasoning enables thinking about objects and episodes as such and orientation in space. Therefore, in this domain, spatial relations within (the composition and structure of objects) and between objects (relative distances, directions, and orientations) acquire prominence because they are crucial in the representation of objects themselves, their location in space, and of the space that surrounds them, as such.

4. Causal reasoning. Objects and people are very often dynamically related, sometimes functioning as the cause of changes and other times as the recipients of causal effects. Causal reasoning enables the grasp of dynamic interactions between objects or persons.

5. Verbal reasoning. Verbal reasoning facilitates interaction between persons, and it is used as a guide to action.

Application of MI in the Education

The application of MI in the Education includes the following steps:

Development of suitable program of training of teachers and school advisers that will allow their familiarization with the application of MI in the schools. Appointment on the importance of the new methods of teaching in the growth of MI of students of secondary education. Specialization of teachers in the use of new pedagogic practices that promotes the growth of MI.

Development of Curricula that is based on MI for the improvement of teaching and learning. Alternative propositions of the MI application in the class.

Application of the MI in the Professional Orientation and Counseling. Diagnose of faculties that composes the MI in the students. Application of scales of measurement of MI in the Professional Orientation and Counseling.

Incorporation of theories of MI in the courses of Annual Program of Pedagogic Training of the School of Pedagogical and Technological Education, but also in the programs of training of teachers.

Application of the MI in the teaching of technological courses

The recognition and the social evaluation of MI in the teaching will practice positive effect on the students as this will contribute in the reinforcement of their self-esteem and develop their self-knowledge. This will have the following important socioeconomic consequences:

Create balanced environment in the education and mental health in the students, after the recognition of the diversity in the educational frame and the acceptance of the differences in the intelligence, (learning, sex, nationality, in body characteristics), and thus

It will decrease the rhythm of the students' abandonment of school.

The application if the MI will change the teaching of the technological courses: will promote the educational awareness and capability to apply new programs of study

based on the MI and educational medias based on the application of new technologies, fact which:

- will give accent in the acquisition of knowledge and skills that will start from the possible elements of students
- will be located with base scales of diagnosis of level of all dimensions of MI,
- will individualize the programs of education for each student, with respect of its rhythm, cognitive profile, as well as its particular faculties and skills.

Pedagogy and Technology: Interdisciplinary Conceptual Approach

Andronikos E. Filios*and Ourania Kalouri, School of Pedagogical and Technological Education, Greece

The aim of the present study is to support the necessity for a "Pedagogical of Technology".

The study of the Pedagogy and Technology and the relation between them is raised from the continuous progress of the technology, the increasing need for new knowledge, the necessity for completed education in high school and finally the wish to create links between Theory and Practice.

Considering the Greek reality and the weaknesses of the educational system, this study is based on an interdisciplinary conceptual approach to the "pedagogical of technology" and it will contribute to the following:

- Students' participation on learning procedure,
- Development of creativity,
- The improvement of self – estimation,
- The development and improvement of personal communication at the school environment.

A new interdisciplinary conceptual approach of the technology is proposed as a result of the absence of power, contents and purposes in technological lessons.

The Philosophy of Technology will be discussed parallel to the fact that "Pedagogical of Technology" is diffused at the teaching lessons at the high school and the lyceum.

The instructional methodology of the lesson and its contribution to the development and maturation of the students are also discussed."

Panel Discussion

Anastassios Koutsoukos, School of Pedagogical and Technological Education, Greece
Panos Polychronopoulos, University of Patras, Greece
Nicholaos Spyrellis, School of Pedagogical and Technological Education, Greece
Gérard Vergnaud, University of Paris V, France

14.30 - 16.30: Symposia

A. Conceptual Change and Motivational Isssues

Organizers: Kaarina Merenluoto and Mirjamaija Mikkilä-Erdmann, University of Turku, Finland

Chairs: Kaarina Merenluoto and Mirjamaija Mikkilä-Erdmann, University of Turku, Finland

Discussant: Erno Lehtinen, University of Turku, Finland

Several researchers have agreed that the processes of conceptual change can not be explained in mere cognitive terms, but that also motivational, metacognitive, and metaconceptual awareness should be considered. In this symposium *Silvia Caravita* will ask how development of interest is related with conceptual change. There she makes make reference to the construct of interest, epistemic interest and interest in a subject. Interest may refer to a dispositional structure of an individual or to current engagements, a psychological state that involves focused attention, increased cognitive functioning, persistence and affective involvement. Internalization and identification have been proposed as the mechanisms that mediate the transition from situational interest to individual interest. *Robin Stark* will discuss about the issues of radical changes which can affect cognitive, meta-cognitive, motivational, volitional and emotional structures, attitudes and values and often have far-reaching consequences on action. The changes can be intentional, but often they are the result of a complex mixture of conscious and sub-conscious experiences. Nevertheless, radical changes can be re-constructed on a rational basis. For the investigation of radical changes, he proposes a combination of three approaches: 1) a perspective focussing on individual characteristics that foster or hamper conceptual change, 2) an elaborated context theory that conceptualizes contexts as perceived and evaluated affordances and constraints for changes, and 3) a developmental perspective which can be inspired by the principle of lifespan-contextualism (Baltes & Staudinger, 2000). *Kaarina Merenluoto, Mirjamaija Mikkilä-Erdmann and Erno Lehtinen* will then present a systematic model of the dynamics of motivational, metacognitive and cognitive processes in conceptual change (Merenluoto & Lehtinen, in press). The model is based on studies on learning disabilities, on the radical conceptual change involved in the extension of the number concept and in the development of the concept of photosynthesis. *Mirjamaija Mikkilä-Erdmann and Janne Lepola* will present results from their studies on the effect of text design and motivational factors on 8th grade students' learning of photosynthesis.

Conceded that Conceptual Change is an object of study, we need to go beyond Cognitive Models

Silvia Caravita, Instituto di Scienze e Technologie della Cognizione, CNR, Rome, Italy

I wish to highlight the frame within which I conceived the overview of the literature that I will present as my contribution to the symposium.

My perspective about conceptual change is defined by a set of statements that I summarize here. Conceptual evolution is a continual process leading to an "agile" mind, not necessarily implying events of change; this evolution is part of the process of learning when learning is for understanding, and not only for acquiring new information and pieces of disciplinary content. Eventual conceptual *change* becomes (and is worth to be) an object of study when what changes bear consequences in the way of viewing reality, of making sense of already stored knowledge, of reasonably filling gaps of ignorance or orienting the search of information. Therefore when it deals with crucial elements of cultural representations of reality, therefore has domain specificity and it also affects general attitudes and beliefs.

Change is an intra-individual (though not solipsistic) process that involves a person, not a mind, it therefore implies many dimensions of the self-system and cannot be studied with merely cognitive models. It may be a tacit and not in control process.

Guided by these assumptions, I will make reference to the construct of interest, epistemic interest and interest in a subject, which only partially overlaps with that of intrinsic motivation. Interest may refer to a dispositional structure of an individual or to current engagements, a psychological state that involves focused attention, increased cognitive functioning, persistence and affective involvement (Krapp, Hidi, Boekaerts). Internalization and identification have been proposed as the mechanisms that mediate the transition from situational interest to individual interest. How is the development of interest related with conceptual change?

The socio-cognitive model of trust will also be discussed (Castelfranchi and Falcone, Gundry), since it calls attention to trust as a mediating variable in knowledge management and sharing.

I will consider self-regulation as participation in learning environments that enhance comprehension as a value, and as a goal that contributes to the construction of a person's identity. Coaching to support organization and recognition of patterns, "bridging strategies" (Minstrell) in teacher's mediation, are valued as empowering components of these environments.

Intentional learning aimed to foster reflective thinking on the processes of knowledge costruction characterises the so-called "powerful learning environments" and may be conducive to conceptual evolution. On the other hand, if the learner is viewed as a whole person whose activity is oriented by multiple goals at different levels, also constructed in a dynamic interaction with the situations, if differences between the the scientific endeavour and knowledge construction driven by everyday life goals are taken into account, teachers' expectations about the dynamics of conceptual evolution may change and many other dimensions of the classroom environment may be recognized as relevant to promote the disposition to openness or readiness to change. How to accept and cope with self-regulated procedures that do not coincide with teacher's predictions or wishes that are all focused on academic goals? Which features of the class climate and practice may influence self-confidence, inner satisfaction for achieved comprehension, purposeful thinking, but also enduring intellectual engagement or commitment to truthfulness, which characterise scientific thinking? Discourse accompanies social exchange (with peers and with adults) on tasks and shapes inter-individual processes of knowledge construction: to which extent does the development in arguing competence affect inner speech and the intra-individiual process of conceptual revision?

Conceptual Change in Conceptual Change Research?

Robin Stark, Saarland University, Germany

In recent years, research on conceptual change was enriched by important aspects (Schnotz, 2001) and new perspectives (Vosniadou, 1999). By integrating motivational aspects in conceptual change research, the studies ultimately go beyond "cold conceptual change" (Pintrich, Marx, & Boyle, 1993). In addition, domain aspects are taken more seriously. The initial narrow focus on well-structured science domains and rather simple tasks has been expanded, at least sporadically (e.g., Limón & Carretero, 1999). These innovations, however, are not far-reaching and consequent enough, neither from a theoretical nor from a methodical perspective (Stark, 2003). In addition to these more "evolutionary" enrichments, more "revolutionary" changes of conceptual change research can be observed. Constructivist (Smith, DiSessa, & Rochelle, 1993) and various situated cognition perspectives (e.g., Caravita & Halldén, 1993; Halldén, 1999; Säljö, 1999) were developed in which some of the central "truths" and more or less implicit premises of more "traditional", cognitivistic positions were seriously questioned. These perspectives accelerate theoretical and methodical progress in conceptual change research. However, central concepts in these perspectives (e.g., the

concepts of context and functionality) are still rather vague and not elaborated enough (Stark, 2003). Besides, they need much more empirical investigation. Starting from a multi-dimensional evaluation of innovations in conceptual change research, an *integrative conceptual change approach* is put forward in which conceptual change is conceptualized as a complex, extensive qualitative change of systems which can be diagnosed on different levels. The paper to be presented focuses on "radical changes" (Ferrari & Elik, 2003) in the sense of individual conceptual revolutions (Thagard, 1992). Examples are a teacher who changes from traditional to innovative forms of instruction or a researcher who changes from employing cognitive to situated cognition perspectives. Such conceptual revolutions involve much more than processes and products which can be interpreted as consequences of "learning". Therefore they cannot be satisfactorily described in pure cognitive terms. Radical changes can affect cognitive, meta-cognitive, motivational, volitional and emotional structures, attitudes and values and often have far-reaching consequences on action. The changes can be intentional, but often they are the result of a complex mixture of conscious and sub-conscious experiences. Nevertheless, radical changes can be re-constructed on a rational basis. People can verbalize these developments, which is an important condition for successful research in this field. For the investigation of radical changes, a combination of three approaches seems appropriate: 1) a perspective focussing on individual characteristics that foster or hamper conceptual change, 2) an elaborated context theory that conceptualizes contexts as perceived and evaluated affordances and constraints for changes, and 3) a developmental perspective which can be inspired by the principle of lifespan-contextualism (Baltes & Staudinger, 2000). This integration of perspectives results in a description of changes as processes and results of ongoing, longer-lasting person-situation interactions. Focussing on isolated characteristics such as domain-specific knowledge and interest (e.g., Limón Luque, 2003) or tolerance of ambiguity (Dalbert, 1999) might lead to interesting insights in local conditions of changes. However, this procedure does not take into account the complexity and dynamics of radical changes. When individual characteristics are focused in the context of the integrative approach advocated here, a holistic perspective has to be developed that aims at identifying profiles of characteristics which are relevant in specific contexts. The main problem of this approach is that time-consuming qualitative methods are needed, at least when authentic changes are investigated that are part of individual biographies. In order to reconstruct subjective theories of radical changes, the so-called *Heidelberger Strukturlegetechnik* (Groeben & Scheele, 2000) could be used. However, experimental research strategies should be employed, too. For instance, students of education could be confronted with ideas of radical constructivism in the context of a seminar or by a learning environment about epistemology. In the outlook of the paper to be presented, advantages and disadvantages of different research strategies are discussed.

References

Baltes, P. B. & Staudinger, U. M. (1994). Wisdom. A metaheuristic (pragmatic) to orchestrate mind and virtue toward excellence. *American Psychologist, 5 (1)*, 122-136.

Caravita, S. & Halldén, O. (1994). Reframing the problem of conceptual change. *Learning and Instruction, 4*, 89-111.

Dalbert, C. (1999) Die Ungewissheitstoleranzskala. Skaleneigenschaften und Validierungsbefunde. Halle: Berichte zur Pädagogischen Psychologie (Nr. 1).

Groeben, Norbert & Scheele, Brigitte (2000, Juni). Dialog-Konsens-Methodik im Forschungsprogramm Subjektive Theorien [9 Absätze]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research [On-line Journal], 1*(2). Verfügbar über: http://www.qualitative-research.net/fqs-texte/2-00/2-00groebenscheele-d.htm

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: Erlbaum.

Limón, M. & Carretero, M. (1999). In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New Perspectives on Conceptual Change* (pp. 137-159). Amsterdam: Pergamon

Limón Luque, M. (2003). The role of domain-specific knowledge in intentional conceptual change. In G. M. Sinatra & P. R. Pintrich (Eds.), *Intentional Conceptual Change* (pp. 133-170). Mahwah: Erlbaum.

Pintrich, P. R., Marx, R. W. & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63*, 167-199.

Halldén, O. (1999). Conceptual change and contextualization. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 53-66). Amsterdam: Pergamon.

Saljö, R. (1999). Concepts, cognition and discourse. From mental structures to discursive tools. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 81-90). Oxford: Elsevier.

Schnotz, W. (2001). Conceptual change. In D. Rost (Hrsg.), *Handwörterbuch der Psychologie* (S. 75-81). Weinheim: Belz.

Smith, J., Di Sessa A. & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, *3*, 115-163.

Stark, R. (2003). Conceptual change: kognitiv oder situiert? *Zeitschrift für Pädagogische Psychologie*, *17* (2), 133-144.

Thagard, P. (1992). *Conceptual revolutions*. Princeton, NJ: Princeton University Press.

Vosniadou, S. (1999). Conceptual change research: State of the art and future directions. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 3-13). Amsterdam: Elsevier.

A Systemic Model of the Processes in Conceptual Change

Kaarina Merenluoto, Mirjamaija Mikkilä-Erdmann and Erno Lehtinen, University of Turku, Finland

Several researchers have agreed that the processes of conceptual change can not be explained in mere cognitive terms, but that also motivational factors (e.g. Pintrich, Marx, & Boyle, 1993), metacognitive factors (Hacker, 1998), and metaconceptual awareness (e.g. Vosniadou, 1999) should be considered. Our aim is to present a systematic model of the dynamics of motivational, metacognitive and cognitive processes in conceptual change (Merenluoto & Lehtinen, in press). The model is based on our studies on learning disabilities, on the radical conceptual change involved in the extension of the number concept (Merenluoto & Lehtinen, 2002) and in the development of the concept of photosynthesis (Mikkilä-Erdmann, 2002). The results from our studies indicate significant differences in the sensitivity to the need for conceptual change and in the tolerance for ambiguity, resulting from the experience of cognitive conflict.

Cognitive and motivational processes of sensitivity. The starting point in the model is a learning situation, in which the learner meets a phenomena calling for new conceptual understanding. There the processes of sensitivity can be used to describe the extent to which he or she is aware of or interested in the novel cognitive aspects of the phenomenon. The cognitive processes refer to the relation between learners' prior knowledge and the cognitive demands of the task, and to their meta-conceptual awareness about their thinking about the subject matter. The motivational processes refer to the learners' tendency to look for novel and surprising features during learning activities (e.g. having a mastery goal orientation see Linnenbrink & Pintrich, 2003). Both cognitive and motivational processes of sensitivity seem then to be related to the students' estimation of his/her certainty.

Low sensitivity leading to low certainty. One possible situation of low sensitivity means that the learner's prior knowledge is completely insufficient for a relevant perception of the new phenomenon. If the situation is socially or personally important to the learner, this confusing situation might induce a feeling of low certainty and more or less random attempts to fulfil the social expectations of the situation or to activate avoidance behaviour. From an instructional point of view, this means that any attempt to create a cognitive conflict would fail to result in the desired conceptual change.

Moderate sensitivity leading to high certainty. In a situation, where the learners' prior knowledge is developed enough for recognising familiar elements in the new phenomenon, but not enough to pay attention to the novel aspect going beyond his/her current conceptions, it might arouse an illusion of understanding which results in (unfounded) high certainty. The high certainty decreases the learner's sensitivity to possible conflicting features of the situation and leads to enrichment of naive models or construction of so-called synthetic models is based on this kind of learning path.

High sensitivity leading to reduced certainty. When the learner's sensitivity to the novel features of the phenomenon is high, it means that he/she has sufficient prior knowledge to understand the cognitive demands of the task, which go beyond his/her current conceptual understanding. Here we refer to the findings of research on comparing experts with novices, were it was showed that showed that, in new problem situations, novices tend to pay attention to the superficial features of the tasks, whereas experts perceive the tasks in terms of underlying general principles (Chi, Glaser & Farr, 1988).

Tolerance of ambiguity. The above processes of sensitivity and of the tendency to pay attention to the novel features in the situation are necessary for productively experiencing a cognitive conflict. However, the learner needs to tolerate a cognitive ambiguity when dealing with the new knowledge system (e.g. Sorrentino, Bobocel, Gitta & Olson, 1988). The concept of the tolerance of ambiguity was first used by Frenkel-Brunswik (1948) then it was understood as a personality variable, but here we consider it to be a more specific variable referring also to the domain of the needed change. It can further be explained as a dynamic process of metacognitive and motivational variables. Thus, coping with a new complex conceptual system is possible only if the learner has sufficient metacognitive skills to grasp conflicting notions. This is, however, not enough, but he/she also needs to be motivated to deal with the ambiguity, and to trust that the experienced conflicts are solvable.

References

Chi, M. T. H., Glaser, R., & Farr, M. F. (1988). The nature of expertise. Hillsdale, NJ: Lawrence Erlbaum.

Frenkel-Brunswik, E. (1948). Intolerance of ambiguity as an emotional perceptual personality variable. Journal of Personality, 18, 108-143.

Hacker, D. J. (1998). Definitions and empirical foundations. In D. J. Hacker, J. Dunlovsky & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 1-24). Hillsdale: NJ, Lawrence Erlbaum Association.

Linnenbrink, E. A., & Pintrich, P. R. (2003). Achievement goals and intentional conceptual change. In G. M. Sinatra & P. R (Eds.), *Intentional conceptual change* (pp. 347-374). Mahwah, NJ: Lawrence Erlbaum Associates.

Merenluoto, K., & Lehtinen, E. (2002). Conceptual change in mathematics: Understanding the real numbers. In M. Limón & L. Mason (Eds.), *Reconsidering

conceptual change. Issues in theory and practice (pp. 233-258). Dordrecht: Kluwer Academic publishers.

Merenluoto, K. & Lehtinen, E. 2004 (in press). Number concept and conceptual change: towards a systemic model of the processes of change.

Mikkilä-Erdmann, M. (2002). Text comprehension and conceptual change: interaction between text design and levels of text comprehension. In L. Mason & M. Limon (Eds.) *Reconsidering conceptual change: Issues in theory and practice* (pp. 337-356). Dordrecht: Kluwer Academic Publishers.

Pintrich, P., Marx, R., & Boyle, R. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*, 167-199.

Sorrentino, R. M., Bobocel, D. R., Gitta, M. Z., & Olson, J. M. (1988). Uncertainty orientation and persuasion: Individual differences in the effects of personal relevance on social judgments. *Journal of Personality and Social Psychology, 55*, 357-371.

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

Responsiveness Versus Resistance to Conceptual Change Concerning Photosynthesis

Mirjamaija Mikkilä-Erdmann and Janne Lepole, University of Turku, Finland

Introduction

The purpose of this study was to examine the effect of text design and motivational factors on 8th grade students' learning of photosynthesis. Research on conceptual change has shown that many students confront difficulties in learning scientific concepts (see Vosniadou, 1994; Vosniadou, Ioannides, Dimitrakopoulou & Papadementriou, 2001; Limon & Mason 2002). On the one hand, difficulties are found to be related to students' intuitive beliefs which often go against scientific knowledge. On the other hand, difficulties in learning counterintuitive concepts are found to be associated with learning materials used in science lessons(Alverman. & Hague, 1989). Acquiring an understanding of scientific concepts through text may be especially difficult for a poor reader who is easily frustrated by poorly written text (Dole, 2000; Mikkilä-Erdmann 2002). Moreover, conceptual change learning also taxes the student's motivation, since it demands persistent effort and concentration on the content of learning. Thus, the student's motivation, the way he or she perceives and approaches a learning task is suggested to play an important role in conceptual change learning (Hynd, Holschuh & Sherrie, 2000).

Method

Eighty-nine 8th grade students participated in the study. They were first given a pre-test concerning photosynthesis. In the following session, students were given either a traditional science text or a conceptual change text and a post-test on photosynthesis. Students could use the text while answering the post-test questions.

Assesment of Motivation

Subject teachers in Finnish language and natural science who had at least seven months' experience of each student's classroom behaviour responded to the motivational orientation rating scales (see Olkinuora & Salonen, 1992). Task orientation, ego-defensive orientation and social dependence orientation were each assessed on *subject-specific* 5-point Likert-type scales from very weak (1) to very strong (5).

Text treatment

Two different versions of a text about photosynthesis were used: the traditional text (TT) and the conceptual change text (CC). The traditional text was taken from a science textbook used in both schools which participated in this study. The CC text was longer (466 words) than the traditional one (408 words) because it involved (a) the *advance warning* of the possible contradiction between reader's beliefs and the scientific ideas in the text and (b) an extended explanation of the difference between the possible misconceptions of the student and the scientific knowledge. (in detail, see Mikkilä-Erdmann, 2001). Secondly, the texts differed in terms of the purpose and focus of the topical organisation. Traditional text aimed to enrich the reader's prior knowledge, starting from a description of the role and function of water in the plant. The conceptual change text, in turn, attempted to contrast reader's prior knowledge with the scientific knowledge from the beginning to the end of the text by stressing the critical difference between plants and animals in the production of energy (in detail, see Mikkilä-Erdmann, 2001).

Pre-test–post-test questions

The understanding of photosynthesis was evaluated by 11 open-ended questions: *two fact-finding* questions (What are stomata?); *two inferential* questions based on the text and presuming understanding of the mechanism and sub-elements of photosynthesis (What are chloroplasts?); *four critical distinction* questions demanding understanding of the ontological distinction between animals and plants ("What does a plant/ a human being need to live and grow and where does it come from?); t*hree generative* questions that required a student to construct a mental model of photosynthesis ("When we eat a potato, we get energy. How does the potato gets its energy?)

Results

Results showed that students who read the conceptual change text performed significantly better on conceptual change questions than students who read the traditional text. Although all three motivation groups progressed significantly on the text-based question of photosynthesis, high task-oriented students performed significantly better on conceptual change questions than non-task-oriented students. Finally, our findings suggest that fostering conceptual change through text design is an important but not a sufficient condition for students with non-task orientation, whose primary motive is not to understand the content of learning but to gain social approval or avoid failure.

Discussion

Furthermore, this study comprises some limitations, and so offers challenges for future research. Firstly, conceptual change learning was measured with a paper and pencil task which may be associated with students' text producing skills. In the future study we have to control the writing skills of the learners. On the one hand, research is needed to analyse from the individual point of view the motivational constraints of conceptual change learning, and on the other hand, a delayed interview could reveal how deep or superficial the change actually was. To promote responsiveness to instruction and learning an analysis of students' motivational dispositions and their interaction with instructional practices such as interactive class discussion and teacher scaffolding is needed.

References

Alverman, D. E. & Hague, S. A. (1989). Comprehension of counterintuitive science text: effects of prior knowledge and text structure. *Journal of Educational Research, 82*, 197-202.

Dole, J. (2000). Readers, texts and conceptual change learning. *Reading and Writing Quarterly, 16*(2), 99-118.

Hynd, C., Holschuh, J., & Sherrie, N. (2000). Learning complex scientific information: motivation theory and its relation to student percpetions. *Reading and Writing Quarterly, 16* (1) 23-57.

Mikkilä-Erdmann, (2002). Science learning through text: the effect of text design and text comprehension skills on conceptual change. In M. Limon Lugue & L. Mason (Eds.), Reconsidering conceptual change. Issues in theory and practice. Netherlands: Kluwer Adademic Publishers.

Mikkilä-Erdmann, M. (2001). Improving conceptual change concerning photosynthesis through text design, *Learning and Instruction, 11*, 241-257.

Olkinuora, E., & Salonen, P. (1992). Adaptation, motivational orientation, and cognition in a subnormally- performing child: A systemic perspective for training. In B. Wong (Ed.) *Intervention research in learning disabilities: An international perspective* (pp. 190-213). New York: Springer-Verlag.

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

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A. & Papadementriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*, 381-419.

B. Changes in Epistemological Beliefs and Effects of Epistemological Beliefs on Conceptual Change

Organizers: Margarita Limón, Universidad Autónoma de Madrid, Spain,
Lucia Mason, University of Padua, Italy,
Christina Stathopoulou, University of Athens, Greece

Chair: Vassilis Tselfes, University of Athens, Greece

Discussant: Marianne Wiser, Clark University, USA

The aim of the symposium is to explore from a philosophical, historical, psychological and educational perspective the interrelation of epistemological beliefs and conceptual change, with an emphasis on the effects of personally held epistemological beliefs on the process of conceptual change. There are important issues to be addressed, and some subsequent questions to be brought up for discussion here. First, how does our psychological understanding of personally held epistemological beliefs, relate to philosophical approaches to epistemology? In other words, what answers can philosophy and history of science give to questions such as what is the nature, and limits of knowledge claims, how do epistemological beliefs change, what is considered as theory change and how does it relate to conceptual change? Furthermore, what kind of feedback do these answers provide to our better psychological understanding of personal epistemological beliefs? Second, do personal epistemological beliefs vary, and to what extent, across disciplines, such as history, psychology, mathematics or physics? How do personal epistemological beliefs, either discipline-specific or not, influence conceptual change in these disciplines, and what are the educational implications?

Conceptual Change in Science: The Case of Theoretical Concepts

Theodore Arabatzis, University of Athens, Greece

The nature of theoretical concepts ("force", "electron", "field", etc.) has been a contested issue in philosophy of science since the early days of logical positivism. Logical positivists distinguished theoretical terms, the linguistic counterpart of theoretical concepts, from observational terms. That distinction was explicated in terms of another distinction between observable and unobservable entities. Unobservable entities were the referents of theoretical terms, whereas observational terms denoted observable entities. Those philosophers identified the

limits of meaningful discourse with the limits of experience. For that reason, the lack of a direct connection between theoretical terms and observable phenomena seemed to undermine their cognitive status.

The above distinctions were challenged on multiple grounds in the 1960 and the 1970s. It was argued that it is not possible to draw a sharp boundary between the observable and the unobservable realms. In any case, even if such a boundary existed, it could not provide a basis for separating the observational from the theoretical parts of scientific language. Furthermore, all scientific concepts have an irreducible theoretical component; they are "theory-laden". Those and similar criticisms reshaped the philosophical landscape. However, the nature of scientific concepts remained a thorny problem. Their "theory-ladenness" implied that theory-change is inextricably tied with conceptual change. And several problematic philosophical consequences seemed to follow, most notably a relativist view of theory-choice and an anti-realist stance towards the ontology of science.

In this paper I will give a brief overview of the problem of theoretical concepts in 20th century philosophy of science (with an emphasis on recent developments) and explore its implications for the issues of scientific rationality and scientific realism. I will argue that conceptual change in science is fully compatible with an account of science as a rational enterprise. Furthermore, I will suggest that the evolution of scientific concepts need not throw doubt, under certain conditions, on their stable identity. When scientific concepts change they may continue to refer to the same entities, properties, or processes. I will illustrate my presentation and arguments with examples from the history of physics.

Epistemological Threads in the Fabric of Conceptual Change Studies

Karen Murphy, Penn State University and Patricia Alexander, University of Maryland, USA

One goal of this symposium is to understand the place of epistemological beliefs in the realization of conceptual change. While some participants in this session will explore the association between epistemological beliefs and conceptual change through correlational or causal studies, our purpose will be to afford an alternative perspective. Specifically, our intent is to examine evidence of the role of epistemological beliefs in the psychological literature on conceptual change. That is, we will seek to shed light on how psychological researchers, implicitly or explicitly, convey epistemological tenets in their conceptual change research. To achieve this end, we will first overview three pillars central to the philosophical study of epistemology (i.e., What is the nature of knowledge?; How does one come to know?; and, Where does knowledge reside?). Second, we will examine the psychological literature on conceptual change for traces of those epistemological pillars. This examination will focus on studies reported in the last 5 years, as well as work of those closely identified with this body of literature (e.g., Mason, Sinatra, and Vosniadou). For example, in our analysis, we will document whether researchers offer an explicit definition of knowledge or if they explain how students come to know a particular fact or concept. Through this analysis, we hope to ascertain how the epistemological threads evidenced in those psychological studies address the central pillars within the philosophical literature. Finally, we will consider the effects of those epistemological perspectives (e.g., knowledge is evidentially-supported fact) on the outcomes and implications reported in the reviewed studies.

Influence of Prior Knowledge and Interest on the Evaluation of Epistemological Beliefs

Margarita Limón, Marta Serrano, Universidad Autónoma de Madrid, Spain, and Laura Massa, University of California at Santa Barbara, USA

Aims of the study

The main goals of our study will be:

a) To evaluate three types of individuals' beliefs:

- epistemological beliefs, that is beliefs about knowledge and knowing (Hofer & Pintrich, 2002);
- beliefs about a particular domain epistemology, that is beliefs about how knowledge is built in a particular discipline, which are the goals of that particular discipline, why it is useful for and which methodology should be employed to collect data or evidences in that particular domain (in our study we will understand domain as equivalent to discipline).
- beliefs about teaching and learning in a particular discipline.

b) To study the relationships among these three types of beliefs.

c) To study the influence of : the level of domain-specific prior knowledge (low and intermediate) and the level of domain interest (low and intermediate) on these three types of beliefs.

Methodology

Four groups of students will participate in the study: undergraduate students (freshmen) in history and in psychology and graduate and PhD students in history and psychology. A pre-test measure of domain interest will be taken. It will be considered that undergraduate students will have a low domain-specific prior knowledge and graduate and PhD students will have an intermediate level of domain-specific prior knowledge (higher anyway than the one undergraduate will have). Also during a pre-test session individuals' will be asked about the teaching and learning they have received on history and psychology.

All participants will complete a questionnaire to evaluate the three types of beliefs. The first part of the questionnaire will be common for all participants and it will evaluate their epistemological beliefs. The second and the third parts of the questionnaire will evaluate participants' beliefs about the epistemology of history and psychology, and their beliefs about the teaching and learning of both history and psychology, respectively. The questionnaire will include closed items and also some problem solving situations where individuals should show and apply their beliefs.

Hypotheses

Our main hypotheses are:

- The main changes between undergraduate and graduate students' beliefs will be found on the evaluation of their beliefs about the epistemology of the discipline.
- There will be a clear relationship between epistemological beliefs and beliefs about the epistemology of each discipline and the teaching and learning of a particular discipline. Thus, for example, those showing an absolutivist view of knowledge and knowing (Weinstock & Kuhn, 2002) will support a coherent view of the domain epistemology that may also influence individuals' beliefs about the teaching and learning of that discipline, although we expect that
- Beliefs about the teaching and learning of each discipline will be more influenced by the teaching of those matters participants have received than by their own epistemological beliefs.

Results

The study is now in progress; therefore we expect to present some of our preliminary results at the SIG meeting.

Effects of Epistemological Beliefs and Learning Text Structure on Conceptual Change

Lucia Mason and Monica Gava, University of Padua, Italy

This study focuses on the effects of two variables that have been recognized as influencing conceptual change and have been investigated separately (Qian & Pan, 2002), that is students' epistemological beliefs and the structure of the text they are asked to learn. On the one hand, it has been documented that the belief in knowledge as complex, uncertain and continuously evolving facilitates knowledge revision more than the belief in knowledge as simple, absolute and certain (Mason, 2003; Qian & Alvermann, 1995; Southerland & Sinatra, 2003). On the other hand, refutational texts - that is texts that directly state alternative conceptions about a topic, refute them and present the scientific conceptions as viable alternatives - are more effective than traditional texts in engendering conceptual change (Guzzetti et al., 1993; Hynd, 2003; Mikkilä-Erdmann, 2002). This experimental study is aimed at investigating the effects of both variables in the complex and dynamic process of learning by knowledge restructuring, through a pre-, post- and re-test design. We expected to find an influence of both variables as well as their interaction. Participants with more advanced beliefs about the nature of knowledge could benefit more from the text designed to help them revise their knowledge. One hundred and twenty-five 8th graders were randomly assigned to two conditions, one requiring students to study a traditional text about biological evolution as presented in a well-known textbook, the other requiring them to study a refutational text addressing their common alternative conceptions about the topic that were ascertained through multiple-choice and open-ended questions. Students' epistemological beliefs were measured using a reduced version of Schommer's (1990) epistemological questionnaire. The belief dimension of knowledge as simple and stable vs. complex and changing was taken into account. Findings from a repeated measures Manova show that both epistemological belief and text type affected conceptual change, as well as the interaction between the two variables. Students with more advanced beliefs about the nature of knowledge changed their alternative conceptions more than students with less advanced beliefs. Similarly, students who studied the refutational text produced more conceptual changes than those who studied the traditional text. The interaction between advanced belief and the refutational text increased the positive effects of the two variables. In addition, the students who revised their alternative knowledge more were found to have greater metaconceptual awareness of their knowledge revision at post-test.

The Relationship between Students' Epistemological Beliefs and Conceptual Understanding in Physics

Christina Stathopoulou* and Stella Vosniadou, University of Athens, Greece

In the present study we explore the relationship between personal epistemological beliefs and conceptual understanding in physics. An evaluation instrument to tap the epistemological beliefs of Greek high school students in physics was developed and was used to investigate the hypothesis that epistemological belief sophistication is a good predictor of conceptual understanding in the area of dynamics in physics. We have adopted a multidimensional model of theory-like personal epistemological beliefs concerning the nature of knowledge (including the dimensions of structure and stability of knowledge) and the nature of knowing (including the dimensions of source and justification of knowledge claims). More specifically, we consider personal epistemological beliefs as individually held explanatory structures with some coherence, consisting of different components / dimensions that are nonetheless, interconnected.

Our theoretical position is that epistemological beliefs can function in ways similar to ontological presuppositions, as constraints on the knowledge acquisition process. As such, epistemological beliefs can have a direct impact on the kind of new information that is picked up from the physical and socio-cultural context and the

way it is explained. They can also have an indirect impact on picking up and explaining information, by influencing certain mediating cognitive and metacognitive functions, such as, for example, study strategies used to accomplish learning goals and self regulation of knowledge acquisition.

Two experiments were designed to investigate the relation of students' personal epistemological beliefs to conceptual understanding in physics. The first experiment involved the development and validation of an instrument, the Greek Epistemological Beliefs Evaluation Instrument for Physics (GEBEP) to tap Greek students' beliefs regarding the nature of knowledge and knowing in physics. A total of 394 Greek 10th grade students participated in the study. The results appeared to support the reliability of the GEBEP in assessing Greek high school students' epistemological beliefs. The second experiment investigated the hypothesis that epistemological sophistication, as measured by the GEBEP, would be a good predictor of conceptual understanding in physics. A total of 76 Greek students were selected from the original sample of 394, on the basis of their scores in the GEBEP. The high epistemological sophistication group consisted of the 38 students with the highest scores in the GEBEP, that is, the top 10% scoring students according to the respective student score distribution, while the low epistemological sophistication group consisted of the 38 students with the lowest scores in the GEBEP, the bottom 10% scoring students accordingly. Conceptual understanding in dynamics was measured using the Force and Motion Conceptual Evaluation (FMCE) measure. The results showed that epistemological sophistication is a good predictor of conceptual understanding in the area of dynamics in physics and gave indications of a causal direction in the relationship between conceptual understanding and epistemological sophistication. Deep conceptual understanding was found to be related only to high epistemological sophistication (since there were no students from the group of low epistemological sophistication that achieved high score in the assessment of conceptual understanding), whereas poor conceptual understanding was found to be related to either low or high epistemological sophistication. This finding provides evidence to suggest that epistemological sophistication is necessary for in-depth conceptual understanding in dynamics.

17.00 - 19.00: Poster Session

Conceptual Change Approach and Students' Levels of Understanding of Ecological Concepts

Gülcan Çetin*, Celil Ekici and Hamide Ertepinar, Middle East Technical University, Turkey

The purpose of the study was to determinate ninth grade students' levels of understanding of ecological concepts with conceptual change approach. In this study, a quasi-experimental design was used. The study took place in the Spring

Semester of 2001-2002 with 82 high school students from four classes taught by two teachers in a Turkish public high school. Two classes were control and two were in experimental. Each teacher had one control and one experimental class. While the control group was instructed by traditionally designed methods, the experimental group was instructed by conceptual change texts supported with demonstrations in small groups (CCTI) during five weeks period (Çetin, 2003).

To determine students' levels of understanding of ecological concepts, the students' responses were closely examined on each of the 17 questions in the Test of Ecological Concepts as pre- and post-test. The TEC consisted of ten multiple-choice questions requiring explanations and seven open-ended questions.

Students' responses to the multiple-choice and the open-ended questions might contain a group of ideas linked together. As a guide, acceptable scientific explanations were written for each question by the experts. Extended lists of ideas in response to each question were set as much as possible in mutually exclusive categories. Thus, the coding schemes were developed and students' ideas were coded related to the students' responses in the reasoning and the open-ended parts in the TEC. Finally, coded students' responses were classified under six categories: sound understanding (SU), partial understanding (PU), partial understanding which includes misunderstanding (PUM), misunderstanding (MU), no understanding (NU), and no response (NR). Similar classifications for similar aims were used in other studies (Simpson and Marek, 1988; Westbrook and Marek, 1991; Keng, 1997; Çetin, 1998).

The scoring scheme according to the students' levels of understanding was given in Table 1 below. For example, if the student responded to the multiple-choice part correctly with a sound understanding explanation, then the score "3" was given.

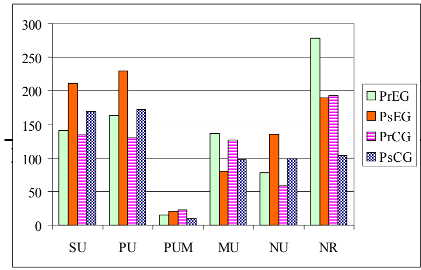
Table 1 Scoring Scheme According to the Students' Levels of Understanding

	Multiple choice part		Levels of Understanding
	Correct	Incorrect	
	Coded scores		
Student's explanation for the multiple-choice question	1	0	NR
		0	NU
	0	0	MS
	1	0	PUM
	2	0	PU
	3	0	SU
	Coded scores		
Student's response to the open-ended question			NR
	0		NU
	0		MS
	1		PUM
	2		PU
	3		SU

The overall results of content analysis of students' responses to TEC showed that the students had six degrees of understanding of ecological concepts in the TEC. Figure 1 displays the students' levels of understanding.

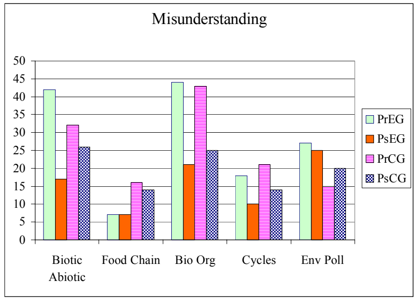
Figure 1 shows that students' sound understanding increased in the experimental and the control groups after the treatment. There was a noticeable increase in students' partial understanding in both groups after the treatment. There was a slight increase in the experimental group students' partial understanding which includes misunderstanding, but a slight decrease in the control group after the treatment. Students' misunderstanding decreased in the experimental and the control groups after the treatment, but this decrease was more for the students in the experimental group than in the control group. The students' no-understanding increased in the experimental and the control groups after the treatment. The number of non-responding students decreased in the experimental and the control groups after the treatment. As a result, the CCTI was more effective in eliminating students' common misconceptions and in increasing the sound understanding and partial understanding of ecological concepts than the traditional instruction.

Figure 1 The Students' Understanding Levels of Ecological Concepts in the Experimental and the Control Groups (PrEG denotes the pre-test for experimental group, PsEG denotes the post-test for experimental group, PrCG denotes the pre-test for control group, PsEG denotes the post-test for control group).



The questions in the TEC were re-organized according to five key concept areas of ecology. These key concept areas were; biotic and abiotic factors, food chain, biological organization, cycles of materials, and environmental pollution. The changes in students' misunderstanding after the treatment in these key concept areas have been presented in the Figure 2 below.

Figure 2. Students' Misunderstandings on Five Concept Areas of Ecology in the Experimental and the Control Groups



The results from the Figure 2 shows that there was a decrease in the students' level of misunderstanding in the control and the experimental groups regarding the key concept areas of biotic and abiotic factors, biological organization, and cycles of materials after the treatment. While there was no change in the experimental group regarding the key concept area of food chain, there was a slight decrease in the control group after the treatment. However, there was a slight decrease in the students' level of misunderstanding in the experimental groups regarding the key concept areas of environmental pollution; there was an increase in the control group. As a result, students' misunderstanding decreased in the experimental and the control groups after the treatment, but the decrease was more in the students in the experimental group.

These findings on student' alternative ideas on ecology can be taken into consideration by science/biology teachers and curriculum developers. Also, the CCTI can be re-designed for ecology courses or other science topics according to the some factors such as class size, class level, and availability of teaching materials.

References

Çetin, G. (2003). *The effect of conceptual change instruction on understanding of ecology concepts.* Unpublished Ph.D. Thesis, Middle East Technical University, Ankara.

Chambers, S.K., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*, 107-123.

Jegede, O. J., Alaiyemola, F. F., & Okebukola, P. A. O. (1990). The effect of concept mapping on students' anxiety and achievement in biology. *Journal of Research in Science Teaching, 27*(10), 951-960.

How to Affect Conceptual Changes?

Barbara Goclowska, Maria Curie Sklodowska University, Poland

The surrounding technologized world becomes more and more interesting. On one hand development of technology saves our time but on the other hand is time consuming. As a result, the time spend on learning by individual students is shorter. The time he spends on thinking and understanding the contents is limited to the minimum. The phenomenon of reciting some knowledge by students not knowing the answer to basic questions becomes more and more frequent. The following example explains it. A student draws the course of rays passing through the lens and quotes the law of reflection correctly. However, when asked why the rays passing through the lens get into the focus – there is no answer.

In the experience acquired by the lecturer during the classes and knowledge obtained from the analysis of the studies described in the literature allow, though not always correctly, to predict the difficulties in understanding or lack of understanding in the area not studied (or studied to a small extend) by other researches.

I chose for my study the wave and harmonic motion. Using the methods of interview and later multiple chose tests I carried out studies of natural knowledge. I used the interview method for the pupils beginning to learn physics. I applied the tests to study evolution of understanding laws and notions that is to study to changes in student's knowledge structure. I am giving examples for better illustration of methodology of research, one for the studies using interview and another for test studies, though most questions asked using interview method were used in tests.

19 pupils took part in the studies using the interview method. The first question in the series was: "What is the position of the pendulum or spring at the time of its quickest movement?" The pupils should determine the position of the pendulum in which it is characterized by the greatest speed. Answering the question about maximum speed, the pupils were looking at the pendulum and spring hung on the thread. Thus they could make the experiment. Some pupils gave a correct answer even they were not able to explain the meaning of the concept "position of equilibrium".

However, some unexpected problems appeared while determining the speed of pendulum. The figures made by most pupils showed *lengthening* of the pendulum thread with more distance from the position of equilibrium. The lengthening took place in such a way that a straight line tangent to the end of pendulum thread could be made.

The pupils had less difficulty which determination of the greatest velocity of the pendulum thread. They also showed lack of preserving the length of pendulum thread. They also showed lack of natural knowledge about velocities and changes of velocities of pendulum during its motion in most pupils. This can be explained by lack of knowledge about energy changes during the pendulum motion and the erroneous understanding of the "equilibrium position" by pupils.

Understanding the relation between velocities and deflection of vibration body during the lessons is is needed for understanding the relation between a force and deflection in further stage. The student should know how to determine during the lesson the position in which the pendulum has the greatest acceleration, how it moves. Lack of such knowledge can make it difficult to understand the concept of waves.

Another example refers to the test question. A piece of cork floats on the pond water surface. Let us throw a stone near the cork to make waves on the water. What will happen when the wave reaches the cork?

The aim of this questions was confrontation of the phenomena observed in reality and those which the student encounter learning physics. While observing waves in nature, particularly those on the water, the student looks at the object on its surface. The object move not only upwards and downwards but also horizontally. Categorization of answers (the student could choose one, many or none of suggested answers) allowed to distinguish the following groups: the cork moves upwards and downwards with simultaneous moving away from the stone with velocity smaller than that of the wave, the cork approaches the pond shore, the cork approaches the stone, none of the answer is correct.

The school handbooks often present strange interpretation for students of the phenomena concerning the waves on water e.g. "waves do not transport matter. A boat moves upwards and downwards when the wave reaches it". Such an illustration of problem is in conflict with students observations and therefore it is not frequently fully understood by him/her.

Most researchers are of the opinion that changes of concepts can made adjusting contents, succession and methods of their presentation etc. to get to accommodation of new laws and notions.

I will focus on the another aspect of studies on student's natural knowledge. I have been observing division into some groups of researchers dealing with teaching physics. There is a group of researchers focusing on searching new elements of student's natural knowledge. Another group are those whose aim was firstly discovery of student's conceptions and secondly preparation of lessons or handbooks in such a way as to help students understand physics correctly to lead to concept changes as frequently as possible. The third group are most authors of handbooks. Being familiar with the results of studies of student's natural knowledge in the area of physics and other science subjects, they prepare the conspectus of lessons or write handbooks. In last case it is not only assimilation of knowledge about education but accommodation as in the final result it leads to such serious changes. Most of the handbooks based on the results of studies on student's natural knowledge.

The title of the article "How to Affect Conceptual Changes" deals mainly with the changes in researcher's reasoning and gives some clues how to lead to the changes of this type in future.

Children's Conceptions of Energy and Force in Inanimate Objects

Olga Megalakaki*, Université de Picardie, France, and Stella Vosniadou, University of Athens, Greece

The focus of this study is to further investigate the understanding of the notions of energy and force. Children, from 10 to 14 years old, were asked a number of questions involving force or energy on inanimates. The sample was divided into two groups. The students of the first group were asked to answer the questions using the term 'force', while the ones of the second group were asked to answer the same questions using the term 'energy'. The results showed that elementary school students use the same criteria (size, weight, position, effort, motion) both for 'force' and 'energy'. High school students use the same criteria for energy, as elementary school students, but change criteria for force by distinguishing between different forces that can be exerted on objects. Concerning the conceptual changes, the two kinds of concepts appear to develop in an asymmetrical way, since the concept of energy is aquired later than the one of force.

Measuring Conceptual Change in Biology with Repertory Grid Analysis

Taeim McCloughlin, St. Patrick's College, Ireland

Repertory Grid Analysis (RGA) provides an objective means for representing concepts using accepted mathematical protocols. In doing so a specific view of what concepts are is implied in the theoretical context underlying RGA; namely, that concepts exist as a personally constructed equilibrium between the mental significance of other concepts and features that can then be represented in a semantic space. Concepts are entities represented according to homeostatic processing. Mathematical protocols such as principal components analysis permits the researcher to transfer mental representations of concepts in semantic space to two (or three) dimensional representations of the same concepts in Euclidian space, for example in Cartesian planes. Similar techniques such as multivariate analysis have been employed in anthropology and folbiology. Because such mathematical protocols provide a precise place-setting of concepts in the form of matrices, conventional statistics (such as Spearman's ρ) can compare changes in the representations of the learner in time: whether as pre and post-testing around a learning intervention, and/or in cross-sectional and longitudinal studies. Previous work in this area examined conceptual change in physics, however this predated advances in computer technology that makes this technique more accessible to researchers and educators alike. This work examines the use of RGA in a cross-sectional study of post-primary learners in biology and explores a range of related techniques with the RGA domain for examining conceptual change.

Turkish Primary Schools Students' Difficulties in Science Topics that Involves Mathematics and Ways to Overcome Them

Sevgi Morali, Esin Pekmez, Elif Turnuklu and Günay Balim, University of Dokuz Eylul, Turkey

In the science curriculum some of the concepts are related with some mathematical concepts and mathematical skills. Lack of mathematical knowledege may be caused some problems in learning science concepts. There may be two main reasons of this problem. First, because of the wrong timing in science and mathematics curriculums, when students face certain topics of mathematics in science class, that topic may be tought later in mathematics, so, they have no knowledge about them yet. Second, although a certain topic is thought in mathematics class, because the relations and applications of mathematics in other subjects not mentioned, students have difficulties to recognise them when they face them in science class. In order to overcome these difficulties mathematics and science curriculums should be reevaluated and necessary arrangements must be made.

The aim of this research is to find out difficulties of 11-13 years-old primary school students about mathematics in science classes in Turkey. This study is a part of Science and Mathematics Integration Project. In order to reach this aim, first of all the science topics were examined in terms of which mathematics concepts needed. Secondly, semi-structured interwieved was conducted by students who are attending primary schools of 6-8 years and science teachers who are teaching in primary schools. These interviews were targeted to obtain teachers and students view about the difficulties that they faced when they are learning or teaching science. Thirdly, a test in science was also used to find out the students mathematical difficulties.

Based on the collected data, the difficulties of the students about mathematical subjects ın science classes were determined and mathematics and science curriculums were evaluated topic by topic in terms of these difficulties. Some suggestions were made about integration science and mathematics, and teaching them.

Relation between Formal Reasoning and Conceptual Understanding

Margarita Kousathana*, Margarita Demerouti and George Tsaparlis, University of Ioannina, Greece

A great effort in science education research has been devoted during the past twenty years on students' conceptions that differ significantly from what is socially

agreed by the scientific community. However, very little effort has been made toward connecting students' conceptions with various psychometric variables. Developmental level, that is, general hypotheticodeductive reasoning ability, is an important predictor variable because most science concepts are based on hypotheticodeductive systems of scientific explanation. The importance of hypotheticodeductive reasoning as compared with domain-specific knowledge has been a subject of considerable debate in the science education literature.

In this work, we examine students' misconceptions in the subject of acid-base equilibrium, but we also investigate the possible connection of developmental level with the misconceptions students hold, the difficulties they experience, and their problem solving capability. The connection of psychometric variables with concepts has received little attention in the literature so far. On the other hand, the importance as predictive variables of developmental level, information processing (working memory and/or mental capacity), and disembedding ability has been studied mainly in connection with science problem solving

A research was conducted in order to investigate misconception among Greek high school students on the area of acid-base equilibria. A questionnaire consisting of ten multiple-choice and eight open-type questions was constructed and utilized. In all items students were called to justify their answer. Students' misconceptions and difficulties in understanding and/or applying the relevant concepts were categorized in seven categories: a) dissociation and ionization, b) definition of Brønsted-Lowry acids and bases, c) ionic equilibria, d) acid-base neutralization, e) pH, f) buffer solutions, g) degree of ionization. Developmental level of students was assessed by means of Lawson's pencil-and-paper Test of Formal Reasoning, in its multiple-choice revised form (Test of Scientific Reasoning).

Results obtained showed that developmental level was coincided in most cases with concept understanding. Students who succeeded in tasks that demand hypotheticodeductive reasoning had better performance in the questions of the test than the other students.

Professional Development Related to Self-Regulated Learning and Conceptual Change for Preservice Teachers: An Intervention-Oriented Literature Review

Monique Brodeur*, Université du Québec à Montréal, Colette Deaudelin, Université de Sherbrooke, Frédéric Legault, Université du Québec à Montréal, Julien Mercier, Université McGill, Canada, Geneviève Nault, Université du Québec à Montréal, and Judith Lapointe, University of Texas, USA

This literature review is part of the effort related to teachers' professional development. Since professional skills in the domain evolve quickly, self-regulated learning is a tool of choice for training teachers (Kremer-Hayon et Tillema, 1999).

Until now, studies of self-regulated learning examined learning in university courses (e.g. Lindner et Harris, 1998), but none has examined the development of professional competencies in practicum. In addition, Wilson and Berne (1999) show that few studies on professional development analyze what people learn from professional development activities. One indicator of this learning is the conceptual change that may occur in learners. In order to sustain preservice teachers in their learning of ICT pedagogical integration during practicum, the following intervention strategies will be implemented, integrating self-regulated learning and conceptual change.

Regarding the development of self-regulation skills, students will be invited to do observation and readings. They will also be exposed to modeling (Zimmerman, 2000). They will use tools such as the learning contract (Anderson et al.,1996), tools establishing a parallel between learning strategies and the results obtained (Zimmerman et al., 1996) and tools helping the learner to become aware of his learning processes (Brodeur et al., 2002 ; Harri-Augstein et Thomas, 1991). To get students involved in conceptual change, researchers will propose them cognitive conflicts, the discovering of existing conceptions, taking into account motivation related to conceptual change. They will also provide models and representations related to the learning objects (self-regulated learning of pedagogical integration of ICT) and encourage metaconceptual awareness (Vosnadou et al. (2001).

A Collaborative Research about Preventing Reading Failure: Changes in the Conceptions and Practices of In-Service Teachers

Monique Brodeur*, Catherine Gosselin, Frédéric Legault, Université du Québec à Montréal, Colette Deaudelin, Université de Sherbrooke, and Julien Mercier, Université McGill, Canada Nathalie Vanier, Université du Québec à Montréal, Canada

In Quebec, as in other countries, there is no consensus among kindergarten teachers about how to prevent reading failure. As the current view suggests to adopt a balanced approach integrating the best of global and phonic approaches (Bos et al., 1999; Pressley, 1998), the aim of this study was to verify how a collaborative research could contribute to teacher's professional development, expressed by change in their conceptions and practices (Guskey's, 2002) toward preventing reading failure, especially about letter knowledge and metaphonological skills. These knowledge and skills are the two strongest predictors of success in reading (Ehri et al., 2001). Twenty-six kindergarten teachers have participated in this collaborative research. During five meetings, from September to April of the same school year, the 17 teachers from the experimental group have been informed of the state of the research and trained to implement a program (Kame'enui et al., 2002) based on this view. Data analysis shows that the project had a desired effect. They reported more favorable conceptions and practices about

the importance of letter knowledge and metaphonological skills than their colleagues from the control group (n = 9). These results suggest that a professional development project, integrating a training to inform teachers about research results and providing them a program and materials, may lead to changes in conceptions and practices. Moreover, this research reveals the possibility to observe changes when the focus is on very specific aspects of knowledge and practices, which is not always obvious when the spectrum is too wide.

Exploring the Efficiency of Concept Mapping Instruction Applied to the Learning of Ecology in Senior High School

Jen-Jang Sheu, National Chung Hsing University, Taiwan

The aim of this research was to explore how much the efficiency of concept mapping instruction model applied to the learning of ecology in senior high school biology courses.

The research design was by quasi-experimental research in which there were two different groups sample students divided who would be in different orientation in future academic or career choices, one natural science-oriented group and one social science-oriented group . Both the two different oriented groups of these sample students were sub-grouped each by the different way of instruction, one by concept mapping model and by traditional teaching model the other.

Research results revealed that those who were applied with the concept mapping instruction model, no matter natural science or social science oriented students, got higher scores than those who were applied with the traditional instruction model in diagnostic test. Besides, there was an interesting finding that there would not be a difference in statistic analysis when applying concept mapping model to both different oriented students, however there were statistics relevance between different teaching strategies which applied to different oriented students. It seems that if the concept mapping instruction model is a more effective teaching strategy in some way.

The Correspondence Analysis Method and its appropriateness to reveal Conceptual Changes

Dimitris Pnevmatikos* and Nikos Koutsoupias, University of West Macedonia, Greece

The paper focuses on a statistical method used to describe conceptual changes on a specific domain of knowledge. One hundred and twenty Greek participants from eight to sixteen years of age were interviewed with a set of questions investigating the conceptual change in the concept of God. The Correspondence Analysis method, a variation o Factor Analysis, was applied to our data. The method produces factorial axes and planes that aid the field expert to draw conclusions based on the examined phenomenon, spherically and to determine subject groupings and their characteristics without any assumptions or hypothesises. Two factorial axes used from the Correspondence Analysis output. Along the first axis and on the right resides the group of participants, which gave answers based on theological accepted ontological assumptions. These answers could be characterised as representing the culturally accepted mental model. On the other side, participants are grouped on the basis of their intuitive ontological assumptions, and could be characterised as belonging to the intuitive mental model. The second axis separates participants, which do not explicitly belong to one of the two groups mentioned above. Groups on the second axis are characterised by answers based on a partially withdrawal of their intuitive assumptions about the deity's ontology, which could be characterised as synthetic mental models. The complete picture of these groupings is shown on the first factorial plane. The evidence coming from this paper indicates that the Correspondence Analysis can be used as a method to study the conceptual change in a specific domain of knowledge.

Improving Conceptual understanding of Factors Affecting the Dissolution Rate: Learning In-Groups Approach in Chemistry Experimental Work

Charalambos Kamilatos, Greece, and Dimitris Stamovlasis, Education Research Centre, Greece

In this study, we examined students' understanding about how factors, such as temperature and steering, affect the dissolution rate of a substance. The subjects were students in tenth grade. We tested a teaching approach, which combined short lectures with demonstration experiments followed by interactive/collaborative work in small groups of four. In the working in-groups session the students had to elaborate questions and to give explanations of macroscopic phenomena connecting them with the microscopic level. We employed a control and an experimental group and pre-tests/post-tests for assessing students' performance. In addition, we examined the prior students' performance in science and the students' developmental level as independent variables. The main research questions were: 1) To investigate students' misconceptions and epistemological barriers related to factors affecting the dissolution rate of a substance, and 2) to test if the experimental teaching approach facilitates understanding at microscopic level. Preliminary data analysis supported the learning in-group session, and it was demonstrated that this approach ameliorated the individual differences. The main findings was that a significant improvement occurred especially in conceptual questions regarding the microscopic level, while learning regarding the macroscopic level was not significantly affected. Note, that in Greek upper-secondary education, laboratory experiments have been introduced recently in the curriculum as an optional teaching approach and it is in a pilot stage. The results of this on-going

research would be suggestive on teaching methodologies concerning the implementation of laboratory work in upper-secondary school chemistry.

The Alternative Models of the Universe: Forming the Historical Approach in School Astronomy

Shu-Chiu Liu, University of Oldenburg, Germany

The poster presents the outline of a cross-cultural study conducted in Taiwan and in Germany. The central issue is the integration of the historical aspect of science into the school curriculum, based on a bilateral reference to the historical development on one end and to the student's alternative conceptions on the other. The study highlights the knowledge domain of observational astronomy, in particular the conceptions of the earth and the heavens (taking the scope of subject concerned in the early history). Two lines of data collection are involved: one is the interviews with young students (3^{rd}-6^{th} graders) and the other the survey on historiography. The result conforms that the common feature between the historical ideas and students' alternative conceptions lies in their structural form, that is, specifically the model of the universe. Students involved in the study presented a limited number of cosmological model, which differs from the accepted scientific notion and can be grouped into the earth-centred and the sun-centred views. The models range from the very primitive to the very advanced according to the modern scientific model. At this point, the historical models in astronomy are suggested to have much instructional implication, given, first of all, their structural form and second, their similar alternative views to the modern science.

Conceptual Mediation: A Strategy to Develop and Change Conceptions of Teaching

Adi Winteler and Claudia Geyer, University of the GAF Munich, Germany

In this presentation we deal with the problem of developing and changing conceptions of teaching and learning. Literature shows that this process needs time (up to 3 years) and effort. This problem can be explained by the natural tendency of our organism to protect what we have learned, especially when we are confronted with new and conflicting experiences, like the change from teaching to learning and the changing role of the teacher (from sage on the stage to guide on the side). The brain mechanism, which is responsible for this tendency, is called proactive inhibition. Proactive inhibition means that the existing (old) knowledge interferes with the retention of new knowledge. This interference shows up in the phenomenon of accelerated forgetting.

We present a new way, helping people to learn new things and to change their conceptions of teaching and learning, without activating this protection mechanism: Mediational Learning. Mediational Learning is a metacognitive strategy using language intentionally to control the effects of proactive inhibition and accelerated forgetting. The result is a faster and longer lasting learning, better retention of what was learned and a stronger motivation to learn and to change.

The Science of Informatics in Education: A Conceptual Dimension and Perspective

Zacharoula Smyrnaiou*, Educational Research Centre, John Orfanos and Ourania Kalouri, School of Pedagogical and Technological Education, Greece

The technology of the computer was handled as a different didactical tool and an alternative learning context in the classroom and contributes to the modification of the contexts of "teaching and learning" (Vosniadou et al., 1994). As a result to this new approach through the computer environment, different CD-ROM were developed. Their use influenced the pupils and the classrooms teachers positively. Indeed, while seeking to exploit the functionalities of the ICTs (diversification of information sources - written, visual and sound, multiplicities of representation forms, access to libraries and databases, possibility of creating discussion forums, of consulting experts, etc), the designers of CD-ROM try to produce tools, which imply other forms of work and other modes of regulation of the activities of learning. The variety of tasks with which the pupils are confronted leads to a diversification of the mental activities that are required of them. The designers are generally concerned with allowing learners to work in an autonomous way, and at their own pace. To learn how to learn, to develop higher cognitive capabilities, to facilitate and optimize learning, to encourage the creation of knowledge. But what has happened in reality? In fact, a technology based learning environment exploits only part of the functionalities that the ICTs allow. The reasons for this are obvious : the limits of the cognitive capabilities of students. In the process of learning, the student's cognitive activity (seizure and coding of information, inference, reasoning, etc.) requires the implementation of multiple controls which mobilize the working memory.

The Contribution of the Technology-Based Learning Environment

Zacharoula Smyrnaiou, Educational Research Centre, Greece, and Annick Weil-Barais, University of Angers, France

Computer equipment and technology based environment intended for education and training using new communication and information technologies (ICTs) contribute to the modification of the contexts of teaching and learning. We present a study concerning the learning of physics (mechanics) while using the 'ModellingSpace' technology based learning environment. After two decades of work centered primarily on the design of technology based learning environments, we have entered a phase where it proves necessary to lead detailed studies of pupils cognitive activities when confronted with these environments. The objective

is to encircle what pupils learn by using the technology based learning environments. We start from the hypothesis that the process of translation between representation systems allow students to learn the meanings of symbols, to familiarise themselves with symbolic systems, to understand them and to help them choose the most pertinent formal systems. We compared the descriptions and manipulations made by the pupils when they had material objects (plastic cars, plane surfaces: paper, plastic…) to carry out the experiments and when they use the ModellingSpace which makes possible to model and simulate symbolically the experiments. It appears that the variational relational approach is much more frequent with the learning environment than with the objects. However, this approach appears especially marked when the pupils had experimented with the objects before the use of the ModellingSpace. These results draw attention to the cognitive benefit of the use of the learning environment if it is preceded by an experimental activity with the relevant objects.

The Development of Challenging Teaching Material

Kostas Vainas, School of Pedagogical and Technological Education, Greece

It is commonly aknowledged that the process of learning is tightly coupled with self-motivation and initiative on behalf of the pupil. If these conditions are to be satisfied the pupil must be interested in what he is doing. This general rule is also valid is "schooling".

If we want our pupils to learn, they must be self-motivated. Hence, it can easily be concluded that the educationalists' duty is to enchance the pupils' "learning motives".

One of the most effectives ways of developing "learning motives" – and to that effect, "endogenic learning motives" – is through the development of challenging teaching material.

The first part of this proposal attempts to stress the importance of developing challenging teaching material within the framework of the didactic process.

The second part singles out some practical ways which the contemporary educationalist can apply at school by making use of the said methodology, i.e. of presenting and negotiating the teaching material, in order to achieve higher quality learning.

Conceptual Approach of the Educational Principles of the "CNC" Course

Andronikos E. Filios*, Stergios Mosialos and Spyros Christodoulou, School of Pedagogical and Technological Education, Greece

The aim of this study is to present a systematic methodology for the teaching and evaluation of the basic principles of the course "Programming…"

The course under discussion is geared to the beginners of the corresponding specialty at TEEs and IEKs and for its teaching we employ the book that has been approved for this purpose by the Pedagogical Institute.

The time allotted to the material intended for examination is 20 hours; the classification of units into two broad classes labelled «theory» and «practice» respectively, and the assignment of appropriate «teaching projects» in accordance with the principles of Special Didactics, is issues that are considered and discussed, as well.

The study then focuses on educational evaluation issues, as is the case with the table containing test specifications for the evaluation of the said course.

The results of the study will hopefully contribute to the improvement of the teaching methodology and the conceptual description of the course under discussion.

Conceptualization and Technology: From Prometheus to Vergnaud

Anastassios Koutsoukos*, School of Pedagogical and Technological Education and Ioannis Antonopoulos, Historical Researcher, Greece

In this article we study the different theories of the concept of conceptualisation in her historical dimension, from antiquity until today.

The opposition mythos / lógos is one of the characteristics of the Greek culture of Antiquity. The criticism carried out by the pre-Socratic philosophers against the traditional mythical beliefs, was continued and carried at its top by another generation of thinkers, the Sophists. Protagoras answers the Platonic allegories with the myth of Prometheus.

Plato makes the distinction between the soul and the body (dualism). By the allegory of the Cave and Line, Plato wants to represent the gradual rise that human knowledge follows world visible to the invisible and understandable world. They are not only the Sophists and Aristotle who were different from the theses of Plato, but also of other philosophers, like the Epicureans, the Stoical ones and the Sceptics.

For Aristotle, the concept occupies an important place: the concept can define only a category (substance, quantity, quality, relation, time, place, position, action and passion). He however rejects the principal thesis of Plato that there is a world of the Ideas (containing only true realities) which is separated from the world of the sensitive things.

Modern theories are inspired by antiquity. Revault d' Allonnes - which refers to the conceptions of Aristotle- introduced the notion of the "mental schemes" into French psychology. Piaget and Vygotski developed other very important theories. Vergnaud presents today its original theory of the “conceptual field”.

The Relation of Candidate Teachers with the Technology: The Case of Pedagogic Applications of Computer

Anastassios Koutsoukos*, School of Pedagogical and Technological Education and Zacharoula Smyrnaiou, Educational Research Centre, Greece

The future teachers need to be familiarised with ICT tools to be able to dynamically participate in the modern technological oriented society as well as to be able to use the advantages and the functionalities of computers in their classrooms.

This paper, based on data from future teachers who study at School of Pedagogical and Technological Education in Athens, aims at exploring the relation of these students with Technology. In particular, in this paper the issue, which is examined, is the way that these students use Word processing after they already have been taught basic functionalities. The task, which is asked concerned the creation of a new file which will contain a) the grades of a class in form of table, b) a text in which they would comment the level of this class as it results from the elements of above table and c) a text in which they would describe the way with which they configure the above file (text and table). That means that we are interesting for their capabilities in creation of a new file, in creation of a table, in configuration of text as well as on the meta-cognitive activity, that is to say, if they had conscience of configuration that they used or became accidentally or became automatically because of the increased functionalities of Word. Twenty future teachers were participated in our research. Every future teacher has worked in one computer individually.

The results show a diversity of files in the creation of table and text. All the future teachers create the text and the table but others use more and others less functionalities of Word (headings, fonts, page numbers, footnotes, pages, colors, etc). Nevertheless, certain future teachers do not write the third activity. Some future teachers write minimal or irrelevant elements in this activity, that means that they created the table and the text accidentally or they have been made automatically by Word and minimal they have succeed in the third activity, consequently they have conscience to the actions that they made.

The Conceptual Evolution from the Mechanical to the Electronic Technology: The 'Drive by Wire' Systems

Vassilis Koutsogiannis*, Euthimios Euaggelou and Maria Koulianou, School of Pedagogical and Technological Education, Greece

The purpose of this research is to study technological evolution that starts with mechanical technology and reaches the electronic technology, as it is related to the way of driving a car. The "drive by wire" system tends to replace the way we use to drive, turn the throttle and steer the wheels. In fact we replace the mechanical setting with a whole parted by sensors and servomechanisms, which in general appear as a new technological development. Based to the "drive by wire" system we can achieve: 1. Better usage of low consumption engines. 2. Correction of driver's mistakes. 3. More advanced steering of the vehicle. 4. Increase of driving safety, even fore the "novice leveled" drivers

This system opposes the everyday experience of mechanics students' and drivers' experience, which provided them with the knowledge that the throttle is connected to the accelerator pedal through steel wire and steering wheel needs a connecting rod to make the car turn. Research presented by automobile factories and published to several technical magazines (R&D-op. 1, 2, 5 and 0-300 mag.-op. 83,92), showed that despite the advantages that "drive by wire" features, is very slowly accepted by mechanics, students, even by customers.

In the present research, we assume that the reasons for misunderstanding the way "drive by wire" works is used and also the difficulty of its acceptance, are related to negative effects of previous knowledge and experience based on conventional technology (Vosniadou, & Brewer, 1994). This assumption is strongly supported by the fact that the new form of technology ("drive by wire") is less observant (it can't be sensed like the previous one), contains a new vocabulary and its developments do not simulate the previous mechanic's, student's and even consumer's experience. For example when a mechanic was asked for the safety that such a system provides, he strongly opposed ignoring the fact that through a flight he trusts his life to a "fly by wire" system! Finally this research wants to show the way to make the new "drive by wire" technology understandable and easily acceptable, is the reorganization of previous knowledge based on the conventional technology (Carey, 1994, Vosniadou, & Brewer, 1992).

Re-Approaching Language as a Science - Society - Human Interactive Conceptual Tool

Constantinos Tzembelicos, School of Pedagogical and Technological Education, Greece

The purpose of this paper is to show that the language can be used in a way that sciences-philosophy can be rejoined in a total research teaching method.

This can be done by reanalyzing the meaning, of the already existing words and finding the parallel meaning in different domains. That is to use language as an in-between the Platonic Idea and the materialization in a realistic object.

This also, might help us to reestablish the conjunction of theories in a total one. As for example we can see that, even totally different at first sight, the term "pressure" can be used to express a dynamic process in a human being, in a mechanical component such as a boiler or in political domain such as a ministry, where in the three of them the applied mechanisms and lows are the same.

On the other hand, using the method of synthetic words we can construct a better mnemonic and critic approach to all matters by using the words not as: example or

extension or information or interactive, but as: ex sample or ex tension or in formation or in terra active.

Finally, the whole thing can be applied either in early teaching or in reorganizing the mnemonic schematic diagram of an advanced personality.

Integration of Information and Communication Technologies into Teachers' Training

Charalambos Mouzakis, School of Pedagogical and Technological Education, Greece

Continuous education for teaching staff is recognized as an essential part of their career and the quality of education. Teacher's training is a basic part of their careers and its main goal is the development of their professional knowledge, their supply with new teaching methods and the offer of opportunities for their self-development. The rapid evolution of information and communication technologies, open new opportunities for accessing information and, also, provides tools for the implementation and designing open and distance training systems. New technologies act as a basis for the design and the implementation of 'virtual classes', enables the learning autonomy of the learner, permits direct communication between trainers and trainees, promotes collaborative learning and, as a result, make the learner/trainer to feel less isolated. These services can be used in educational environments to provide several aspects that are often missing with traditional distance learning techniques, such as, tutor-student dialogue, individual feedback, group interaction and discussion, collaborative work etc. Teachers are the defining factor of the successful fitting of every innovation, that's why they should be encouraged in their effort to incorporate the technological services in their every day work as far as technical issues (material and technical substructure, technical support) and issues of information utilization (information about the communication possibilities, possibilities of partnership among colleagues of other school in various projects) are concerned.

Holistic and Cross Curriculum Approach and Educational Performance: The Example of Modern Technology in Modern Greek Language Teaching

Irini Korre and Anna Markopoulou, School of Pedagogical and Technological Education, Greece

The segmentation of scientific knowledge in independently and completely taught units has been considered until today, essential in familiarizing students with collective knowledge. However, problems that have occurred from the segmentation of academic knowledge in combination with new scientific, educational and social perceptions concerning the nature and the method of learning, and what the context of a contemporary general education should be, have led to the holistic connection of individual subjects.

Such methods reflect the complexity of modern and future society, and provide students with the necessary means of confronting life after school. Nonetheless, modern professions require skills that are based on the unification of various fragments of knowledge and consist of a network of inter-related skills and capabilities: a network that has difficulty in corresponding to the division and segmentation of curriculum.

The use of contemporary technology (PC) in language teaching promotes the connection between the two subjects which leads to a thorough analysis of basic topics and projects the parameter of cross curriculum and holistic approach in the classroom.

Practical Exercises of Teaching: For an Alternative Evaluation

Dimitrios Lagos, School of Pedagogical and Technological Education, Greece

At this presentation the process of teaching and learning and teaching models in the education of trainers (Practical Exercise) and the methods of evaluation are discussed.

The progress in Pedagogical and Teaching Science demands an interdisciplinary approach to the education of the trainers that will not be based in one method but in the combination of alternative teaching models and specially models of evaluation.

These models will allow us to distinguish the psychological, cultural, historical, parameters of didactic learning situation and will provide processes of communication, interaction, co-operation, initiation and learning through the educational action.

Saturday, May 22nd

09.00 - 11.00: Keynote & Panel Discussion

Chair: Peter Machamer, University of Pittsburg, USA

Keynote Addresses

On the Grammar of Conceptual Change

Aristides Baltas, National Technical University of Athens, Greece

The paper will focus on conceptual change in the natural sciences and particularly physics, arguing that radical scientific discovery can profitably be viewed as a widening of the grammatical space available to the inquiry. The sense of "grammar" at issue is that proposed by Wittgenstein, both early and late. It will be shown that although incommensurability between succeeding paradigms and a commutication breakdown between those holding them are unavoidable, objectivity and scientific progress are not imperilled".

Constraints on Knowledge Acquisition

William F. Brewer, University of Illinois at Urbana-Champaign, USA

In earlier work with Stella Vosniadou I investigated children's acquisition of knowledge about observational astronomy (e.g., the shape of the earth, the day/night cycle). We found that across children there was a small set of initial theories about these phenomena. For example, their explanations of where the sun is at night included theories that involved occlusion mechanisms such as clouds coming in front of the sun or movement mechanisms such as the sun going out into space, or moving down behind mountains or trees.

Since the adult culture that these children were exposed to accepted a Copernican account of these phenomena we argued that the children's theories did not derive from the adult culture but must have come from the children's basic human cognitive equipment interacting with aspects of the perceived natural world. This is clearly a strong claim of universality. Data on children's theories of observational astronomy show strong similarities across cultures and thus support the claim.

In this talk I want to explore another implication of the claim of universality. The constraints that lead the children to a limited set of theories may also have been operating in the adults who produced the very earliest cosmologies in different cultures and therefore we might expect very early cosmological models to show strong similarities to those we have uncovered in young children. Examination of accounts of the shape of earth and the day/night cycle found in the earliest Greek cosmologies, early Egyptian cosmology, and early Hebrew cosmology appear to show strong similarities to the child data and thus provide additional support for our universality hypothesis.

I will conclude the talk with some speculations on the nature of the constraints on theory formation in children and adult scientists at the early stages of the development of science. I argue that the limited number of theories developed by the children and the scientists to account for the phenomena of observational astronomy are constrained by the use of theory evaluation criteria such as empirical adequacy, plausibility, consistency, and simplicity.

Panel Discussion

Lillian Hoddeson, University of Illinois at Urbana-Champaign, USA
Nancy Nersessian, Georgia Institute of Technology, USA
Stathis Psyllos, University of Athens, Greece
Matti Sintonen, University of Helsinki, Greece
Stavroula Tsinorema, University of Crete, Greece

11.30 - 13.30: Paper Sessions

A. Learning Environments

Chair: Vassilios Kollias, University of Thessaly, Greece

Discussant: Vassilios Kollias, University of Thessaly, Greece

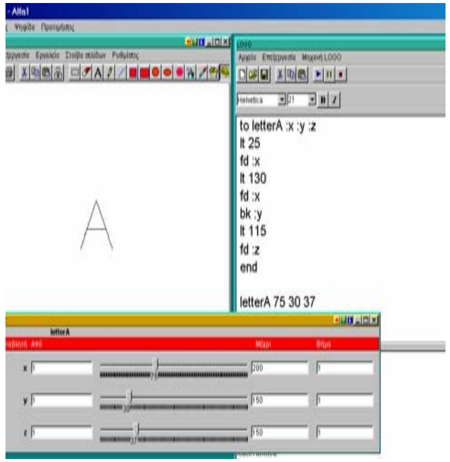
Normalizing Geometrical Constructions: Children's Activity Generated Meanings for Ratio and Proportion

Giorgos Psycharis* and Chronis Kynigos, University of Athens, Greece

In this paper we report research aiming to explore 13 year-olds' mathematical meanings constructed during activity involving ratio and proportion tasks in their classroom. The students worked in collaborative groups of two using 'Turtleworlds', a piece of geometrical construction software which combines symbolic notation through a programming language with dynamic manipulation of variable procedure values (Kynigos, 2002). They were engaged in a project to build figural models of capital letters of varying sizes in proportion by using only one variable to express the relationships within each geometrical figure. In this paper we discuss children's

normalising activity characterized by engagement with 'corrections' of distortions to figural representations using the available computational tools. This process was characterized by: (a) pupils' gradual focus on relationships or dependencies between objects by exploring the graphical feedback and (b) the emergence of mathematical meanings for ratio and proportion.

Theoretical framework



We adopted a broadly constructionist framework (Harel and Papert, 1991) for our work taking also into account the situated cognitionist view about the complex ways by which knowledge is shaped within a particular setting (Lave, 1988). Proportional reasoning has been the object of many research studies which have revealed that children view ratio and proportion tasks as requiring addition and not multiplication and thus chose an 'additive strategy' for solving them. More specifically, it has been reported that geometrical enlargement settings provoke more addition strategies than any other one while students can hardly identify a ratio relationship regardless of context and numerical content. However, there have also been reported the benefits of the use of computational tools in children's proportion strategies derived from interacting within specially designed microworld settings that facilitate linkages between visual, numerical and symbolic representations of geometrical objects (Noss and Hoyles, 1996). In this report, we thus build on prior computer-based geometrical enlargement tasks with the aim to exploit kinesthetic control *as a process*. Our focus was on students' dynamic manipulations of the geometrical objects *during* the ongoing experimentation through actions with symbolic notations and representations since in proportional tasks of that kind graphical representation of objects is tightly related to the use of algebraic relations.

Research setting and tasks

The pedagogical design of the software involved an integrated use of both formal mathematical notation and dynamic manipulation of variable values. In Turtleworlds, what is manipulated is not the figure itself but the value of the variable of a procedure by the dynamic manipulation feature of the software called 'variation tool'. After a variable procedure is defined the tool provides a slider for each variable. Dragging a slider has the effect of the figure dynamically changing as the value of the variable changes sequentially. Dragging thus affects both the graphics and the symbolic expression through which it has been defined, combining in that sense these two kinds of representations which appear rather static in most of the enlarging geometrical settings. In the context of the research we also place emphasis on the task design as offering a research framework to investigate *purposeful* ways that allow children to appreciate the *utility* of mathematical ideas (Ainley & Pratt, 2002). According to the task pupils are asked to manipulate geometrical figures in a meaningful way i.e. to construct models of capital letters of different sizes that will not "distort" under size changes which keeps up with the functionality of any font both in and off the computer. The research took place in a secondary school with two classes of 26 pupils aged 13 years old and two mathematics teachers. During the activity, which lasted for 32 hours in total over 9 weeks, each of the two classes had two 45-minute project work sessions per week with the participant teachers. Each class had the task to construct all the capital letters of the alphabet called '*The Dynamic Alphabet of your own class'*. During the classroom activity, the students were engaged in building models of capital letters of variable sizes, having initially been told that the aim was for each letter procedure to have one variable corresponding to the height of the respective letter.

Method

We employed an ethnographic approach to the school community. Our objective was to gain insight into (a) the nature of the meanings of ratio and proportion constructed by pupils during their explorations and (b) the ways in which meaning generation interacted with the use of the available tools. During the activity, we took the role of participant observers and focused on one group of students in each class (focus groups), recording their talk and actions and on the classroom as a whole recording the teacher's voice and the classroom activity. In our analysis we used a generative stance, i.e. allowing for the data to shape the structure of the results and the clarification of the research issues.

Results

In the selected episodes are presented different kinds of normalising activity interrelated to the simultaneous emergence of mathematical meanings. These episodes illustrate the dialectic relationship between the evolution of normalising and pupil's progressive focusing on relations and dependencies underlying the current geometrical constructions and its representations. The key difference amongst the episodes is that in the evolution of the activity the appreciation of the feedback was much more closely bound into the articulation of the proportional relationships involved. In the first episode an icon-driven interpretation of the task to build a bigger letter in proportion with the original pattern bypassed altogether the internal relationships of its structure and it was not related to any kind of proportionality. In the second episode children seemed to gain control of the normative process according to specific proportional rules. In the third episode pupil's previous experience with the computational tools had been moving in the direction of manipulating the graphical object and its symbolic relations as a source to bring new meanings to the questions arose by the current construction task. The research highlights the relationship between normalising, task design and computer environment as coherent parts of the emergent pedagogical setting which favors experimentation and meaningfulness.

References

Ainley, J. & Pratt, D. (2002) Purpose and utility in pedagogic task design, *Proceedings of the 26th PME Conference*, Norwich, England, Vol. 2., pp. 17-24.

Harel, I. and Papert, S. (eds.) (1991) *Constructionism: Research Reports and Essays*, Ablex Publishing Corporation, Norwood, New Jersey.

Kynigos C. (2002). Generating Cultures for Mathematical Microworld Development in a Multi-Organisational Context. *Journal of Educational Computing Research,* Baywood Publishing Co. Inc. (1 and 2), 183-209.

Lave, J. (1988) *Cognition in Practice*, Cambridge: CUP.

Noss, R. & Hoyles, C. (1996) *Windows on Mathematical Meanings*, Kluwer.

Exploring Students' Learning in Environmental Education: An Intentional Perspective on the Influence of Students' Values in Knowledge Development

Cecilia Lundholm, Stockholm University, Sweden

Purpose

In the proposed paper students' learning in environmental education is investigated with a focus on the way that values and emotions become an aspect of the learning process. It is discussed how values and emotions become a difficulty and an obstacle in the cognitive developmental process.

Theoretical Framework

'Conceptual change' has emerged as a description of learning, whereby learning is seen as a process of replacing common-sense knowledge with scientifically accepted ways of conceptualising the world (Posner & Strike, 1982). This process is further seen as a rational and intellectual activity. Critics of such a view have pointed out that learning is not a matter of replacing less qualified or naïve conceptions of phenomena in the world, but is rather a question of understanding in what situations and within which genres different knowledge is useful and appropriate (Caravita & Halldén, 1994; Halldén, 1999; Halldén, Peterson, Scheja, Haglund, Österlind & Stenlund, 2002; Petersson, 2002). Learning is thus seen as a process of differentiating between various contexts.

The article draws upon two case studies (see also Lundholm, 2003; Lundholm, in press a, b) where students' interpretations of course content in ecology, and a task on 'environmental reports' are analysed as frames of reference, here defined as *contexts.* Thus context is not seen as a place or situation but as description of a mental and cognitive 'framing' of concepts or phenomena that we have, or that is actualised by a task in school. Halldén (1999), Wistedt (1994), Wistedt, Brattström & Martinsson (1997) describe the different ways students interpret and contextualise tasks given to them in classroom situations. Students' and teachers' interpretations actualised in school settings can be described as being either common sense or theoretical, but also as different theoretical contexts representing different disciplines or genres (Wistedt, 1998). Students' alternative contextualisations can also be seen as an expression of values referring to norms and values in society and the context can therefore be characterised as cultural. An empirical example of this is given in a study by Halldén (1999) showing how students contextualise a task about the ecological relation between animals and plants, in biology, as a problem about the extinction of species. The way the students interpret the task becomes intelligible when we consider the ongoing debate in today's society, in Sweden, about the extinction of species and biological diversity. Their cultural contextualisation of the task into an environmental discussion concerns questions of value judgement such as; what species should be saved? Which should die?

Looking at learning from an intentional perspective means taking account of the students' aims for engaging in the learning process and considering these when analysing their interpretations (Halldén 1982, 1988 & 2001) and Wistedt (1987) have investigated the ways in which students interpret tasks, given to them in the school setting, as 'problems'. 'Problem' is a term that describes what the students are trying to accomplish. Furthermore, the 'problem' he or she is trying to solve can be interpreted in a wider sense by taking into account the student's aims and goals. By ascribing a student a plausible goal that he/she is trying to realise, defined here as 'project', the students' interpretation of the task becomes intelligible.

In this paper the focus is on the influence of students' values and the affective side of learning. According to Head (1989) the affective aspect of concept development in science has not reached enough attention.

Methodology

The methodology can be described as a qualitative case study approach and the two case studies that the article draws upon were conducted as follows:

- In the first case study lectures in a compulsory course in Ecology (4 credit points) taken by first-year civil engineering students were tape-recorded and observed. The course was given during the spring term of the year 2000 at the Royal Institute of Technology (KTH) in Stockholm. There were 103 students in the class, and six of these students, two women and four men, were selected for interview. These were also tape-recorded and transcribed.

- In the second case study a group of four students, three women and one man, worked on a task on 'environmental reports' within an environmental course of 10-credit points, 'Environmental control for biologists', at Stockholm University in 1998.

The students' group work was observed, hand-written notes were made of their activities and the discussions were tape-recorded. The group worked over a period of three weeks.

Conclusions

When meeting a course content on ecology and environmental issues the civil engineering students were provoked by values that see mankind as simply being harmful to nature. The content also raised issues concerning human beings in relation to nature. The students discussed the notion of humankind as being within or outside the eco-system, and this seems to have led them to consider the moral aspects of human actions and the effects of these actions on nature. This means that the students' interpretations of the course content can be said to be embedded within a cultural context of values and norms. The students seemed to believe that the teacher had, implicitly, expressed the viewpoint that human beings have affected nature only in a negative way and that the teacher had neglected to highlight the positive effect which that impact has had on humans. In talking about these aspects of values, the students showed irritation and indignation and seemed to find the whole issue quite provoking. Furthermore, there was also a moral issue of 'saying one thing and doing another' that one of the students asserted the teacher and his actions.

When biology students solved the task on 'environmental reports', values and judgements about the companies were brought to the fore. It became difficult for the students to work phenomena 'environmental report' by reading and analysing 14 different reports. The students started discussing the companies' environmental work, thus leaving the written reports aside and instead focussing on 'real life' within the companies.

The results are discussed in relation to possible 'projects' that can be ascribed the two groups of students as well as the fact that environmental issues often can be characterized as environmental problems and therefore call for some kind of solution and action.

Theoretical and Educational Significance

It is hoped that the findings can contribute to a discussion about the ways values become an aspect of cognitive development and raise questions regarding the rational aspect of the process.

References

Caravita, S., & Halldén, O. (1994). Re-framing the problem of conceptual change. Learning and Instruction. 4, 89-111.

Halldén, O. (1982). Elevernas tolkning av skoluppgiften [The learners' interpretation of the school task]. PhD Thesis, Stockholm University, Department of Education.

Halldén, O. (1988). Alternative frameworks and the concept of task.

Cognitive constraints in pupils' interpretations of teachers' assignments. Scandinavian Journal of Educational Research, 32, 123-140.

Halldén, O. (1999). Conceptual change and contextualization. In W. Schnotz,

S. Vosniadou, & M. Carretero (Eds.), New perspectives on conceptual change. Amsterdam: Pergamon. 53-65.

Halldén, O. (2001). Social konstruktionism, konstruktivism och intentionell analys som heuristiskt verktyg i kvalitativ analys. [Social constructionism, constructivism and intentional analysis as an heuristic tool] In O. Halldén, M. Scheja and H. Jacobsson Öhrn, Intentionell analys. [Intentional analysis Research Bulletins from the Department of Education, no. 65,Stockholm University.

Halldén, O., Petersson, G., Scheja, M., Ehrlén, K., Haglund, L., Österlind, K., & Stenlund, A. (2002). Situating the question of conceptual change. In M. Limon, & L. Mason (Eds.), Reconsidering Conceptual Change: Issues in Theory and Practice. Dordrecht: Kluwer Academic Publishers.

Head, J. (1989). The affective constraints on learning science. I P. Adey (Ed.) *Adolescent development and school science.* London: The Falmer Press.

Lundholm, C. (2003). Att lära om miljö. Forskare- och högskolestuderandes tolkningar av ett miljöinnehåll i utbildningen. [Learning about environmental issues. Undergraduate and postgraduate students' interpretations of an environmental content in education] PhD Thesis. Department of Education,Stockholm University.

Lundholm, C. (in press, a). Case studies – exploring students' meaning and elaborating learning theories. *Environmental Education Research,10* (1).

Lundholm, C (in press, b). Learning about Environmental Issues in Engineering Programmes. A case study of first-year civil engineering students' contextualisations of an ecology course. *International Journal of Sustainability in Higher Education.*

Piaget, J. (1929/1989). The child's conception of the world. U.S.: Littlefield Adams

Petersson, G. (2002). Begreppsutveckling genom imitation, generell assimilation och differentiering. Hur studenters uppfattning förändras over tid i en akademisk utbildning. [Development of concept through imitation, general assimilation and differentiation. How medical and nursing students'conceptions develop over time] PhD Thesis. Department of Education, Stockholm university.

Posner, G., Strike, K., Hewson, P. & Gertzog, W. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. Science Education, 66, 211-227.

Wistedt, I. (1987). Rum för lärande [Latitude for learning]. PhD Thesis,Department of Education, Stockholm University.

Wistedt, I. (1994). Everyday common sense and school mathematics. *European Journal of Psychology of Education, 9*(1), 139-147.

Wistedt, I. (1998). Assessing student learning in gender inclusive tertiary mathematics and physics education. *Evaluation and Program Planning.* Special issue on New assessment methods in mathematics and science: Comparing and contrasting styles and outcomes, L. Burton (Ed.).

Wistedt, I., Brattström, G., & Martinsson, M. (1997). Ways of knowing mathematics in gender inclusive tertiary education. An intentional approach to students' understanding of mathematical induction. Papper presenterat vid EARLI konferens i Aten, Grekland, 26-30 augusti 1997

Proactive Agents and Children's Conceptual Learning

Eva Tuominen* and Kari Petrola, University of Tampere, Finland

In an on going research project our research group is developing a computer-based and proactive agent-technology using simulation environment that will support pre- and primary school aged (6-8 years old) children's exploratory and conceptual learning. The domain area of the environment is nature and natural phenomena, especially phenomena that are related to the concept of Earth and its shape. The environment applies multimodal interface technology, which means that in addition to visual and auditory feedback; also the sense of touch is being used as an additional channel. The primary goal of the project is to create a learning-environment that can be used by both visually impaired and normally seeing children (Kangassalo & Raisamo 2002).

In our research group we are doing pioneering work on proactive learning systems, and as far as we know, this kind of research hasn't been done before. In the presentation, both the pedagogical model of the learning-environment and the proactive agents' actions will be presented at a very concrete level. Also the question of different agents (programmable vs. human) and their roles in supporting conceptual learning will be discussed.

The pedagogical approach of the computer-based environment is based on exploratory learning. This means that a child can explore the selected phenomena according to his/her own interests and questions using the program as an "exploration tool". An important basis for conceptualising and analysing child's exploration process in the program is derived from the interrogative model of inquiry (Hintikka e.g. 1985, 1988). This model has initially been developed by Jaakko Hintikka for the purposes of philosophy of science in the 1970s. It's a model of scientific reasoning, where scientific procedure is viewed as information seeking by questioning (Hintikka 1985). In the interrogative model it is assumed that when an inquirer starts his inquiry, he has some background knowledge of the world (presuppositions) as well as something that he wants to know (i.e. an unsolved problem). Usually the solving of the problem requires some auxiliary information as well as dividing the problem into series of smaller questions. Shortly, according to the interrogative model of inquiry, the inquirer tries to derive an answer to his/her initial question - which is often explanation-seeking in nature - by using his existing knowledge and by formulating and seeking answers to smaller questions. This way, new presuppositions begin to accumulate and the inquirer can –step by step- approach the answer to the initial, principal question of his inquiry. In this research, applying this model means that a child's learning is viewed as an active process guided by his/her own questions and previous knowledge. Because the child's interests and questions are considered as a starting point for explorations, there are no predestined "routes" how the child should proceed in the program. However, it has been emphasized that children need guidance and support for their explorations in order to achieve progress and deepen their understanding (Hakkarainen, Lonka & Lipponen 1999, 204-205). Especially with regard to conceptual learning, it is important that children are supported to progress behind the observable phenomena, to search for explanations and "key ideas" which are crucial in understanding the phenomena in question. For this reason, we have applied programmable proactive agents in the construction of the environment.

Agents are usually "lifelike" characters that act at the computer-screen. They can for example guide learners in problem solving and provide feedback for learners' actions. In this system, the agents' actions will be based mainly on auditory and haptic feedback, since the system is developed especially for visually impaired children. However, this provides possibilities also for normally seeing children to receive and use information obtained through multiple sense modalities. Proactivity, on the other hand, can be defined as anticipative computer-technology. It adapts according to the user and situation, predicts the users' intentions and acts accordingly (Lindèn 2002).

The proactive agents aim at supporting children's conceptual learning by deepening and extending children's independent exploration process in the program. By creating learner-profiles the agents can initiate proactive actions, for example suggest interesting information or further exploration possibilities for the child at the appropriate times (Kangassalo & Raisamo 2002). The agents scaffold the child's exploration process mainly by asking questions and making suggestions. In principle, the agents guide the explorations from familiar everyday contexts towards the causes and explanations of the phenomena. The knowledge how children usually acquire scientific concepts (in this case results from the studies concerning children's conceptions of the Earth) is being used when designing the environment and agents' actions. However, it is considered important that the support doesn't replace child's own thinking, but rather stimulates the thinking and encourages the formation of questions in child's mind. As in the interrogative model of inquiry, the child's own questioning and activity are considered as a basis for knowledge construction. Hence the agents don't make any decisions for the child or make the child to explore anything. In any moment, the child can choose either to hear what the agents ask or suggest, or to ignore them. As the child's explorations proceed,

the agents' support may also – step by step – decrease. In summary, the agents aim at scaffolding each child with respect to his/her capabilities and interests.

References

Hakkarainen, K., Lonka, K. & Lipponen, L. 1999. Progressive Inquiry: How to Overcome Limitations of Human Intelligent Activity. In Finnish. Helsinki: WSOY.

Hintikka, J. 1985. True and false logics of scientific discovery. In J. Hintikka & Vandamme, F. (eds.) Logic of Discovery and Logic of Discourse. New York: Plenum.

Hintikka, J. 1988. What is the logic of experimental inquiry? Synthese 74, 173-190.

Kangassalo, M. & Raisamo, R. 2002. Proactive agents supporting children's exploratory learning. Research plan.

Lindén, G. 2002. Proactive computer-technology – Does the computer know, what you want next? In Finnish. Tietoyhteys. 24.9.2002.

Instruction of Friction with the Educational Software 'Vectors in Physics & Mathematics'

Antonis Koukoutsakis, University of Athens, Greece

Review of literature

This study aimed to evaluate the learning outcomes from the use of the educational software "vectors in physics and mathematics" at the teaching of the concepts of static friction and kinetic friction. The general objective of this software is to connect vectors with everyday events through selected problems and activities. Its main designing principles are:

- It emphasizes on student's involvement in authentic activities from real world.
- It supports creative activities of students and allows them to have control over the learning procedure, but also provides assistance and guidance when needed.
- It takes under consideration the students' experiences and allows them to be expresses. Therefore, the students can test the validity of their beliefs, face their misconceptions and become aware of their beliefs' limited explanatory power (metacognitive awareness).
- It encourages collaborative learning and communication among students and teachers.
- It is accompanied by carefully designed scenarios and directions for its exploitation from a pedagogical point of view. It also provides the chance of testing "what – if" hypotheses and scenarios.
- In several scenarios (e.g., the scenario "at the post office" which was used at the instruction), the software provides the chance of combinative use of

multiple representations of some phenomena. The effects of the dynamic manipulation of one of these representations appear at the rest of the representations.

The basic principles of learning and instruction, which have resulted from the research of cognitive psychology, have been used at the design of the instruction. A few of these principles are:

- Active involvement of students.
- Meaningful activities.
- Relating new information to prior knowledge.
- Aiming towards understanding rather than memorization.

The research hypotheses are that 1) the instruction with the software will be effective in the achievement of conceptual change for the misconceptions revealed by the pretest on the concept of friction and 2) the instruction with the software will be more effective at the attainment of the teaching goals than the instruction without the use of the software.

We must mention that the main reason of the students' difficulties to understand some scientific concepts is attributed to the formation of alternative ways of interpretation, known as misconceptions or preconceptions. Children resist to the new information that cannot fit with the existing schema. The radical reconstruction of their subjective representations, although necessary, it is not an easy task for the teacher. Students' realization of the existence of their beliefs and their explanatory insufficiency are necessary conditions that will lead to the removal of misconceptions.

Talking about misconceptions, a common belief among students is that a motion requires a force or respectively, "no motion – no force". For example, most students claim that if a box remains still on the horizontal surface of a table, then no force is exerted or the only force on the box is its weight. We mention a study by Osborne & Freyberg (1985), where students – aged from 7 to 19 – were provided with a picture showing a man pushing a car and a comment that the car had broken down and that the man tried but did not manage to move it. The students were asked if any forces were exerted to the car. A common answer was that "no force is exerted because the man cannot move it".

Method - Results

One whole class of 34 10th grade students participated at this study. The experimental group consisted of 18 students and the control group consisted of 16 students. A few days before the instruction, all students took part at a pretest aiming to investigate their beliefs about friction and their misconceptions about Newton's Laws of Motion. The instruction of friction was divided in two sessions. The first session was dedicated to the instruction of the static friction while the second session was dedicated to the instruction of the kinetic friction. The

experimental group was taught at the computer lab while the control group was taught at the classroom by the schoolteacher. Finally, a few days after the instruction all students took part at a posttest.

The findings from the pretest indicate that most students face difficulties to implement Newton's First Law when a horizontal force is exerted on a still object by a man and they mention either that the static friction is greater than the horizontal force from the man or that the only (horizontal) force on the object is the one from the man.

The students of the experimental group were given working sheets to complete with the results from the experiments they conducted through the software.

Some students of the experimental group, which had appeared some misconceptions at the pretest, when were asked to contrast the results of the experiment with their initial beliefs, they revised them. This is contingent with Olson's finding (1988) that "when students have the chance to see the results of their hypotheses and to try some alternatives, they become aware of the different schemas and rules". What's more, the ease for prediction shows that a large number of students (of the experimental group) understood the factors that influence the static and the maximum static friction.

As students get familiar with a meaningful problem while working with various computerized models, they start to obtain useful experiences and skills and change the way they think. This procedure helps them to understand some abstract concepts by going beyond their previous beliefs. For example, at the pretest it was found that most students believe that static friction is an invariable force, greater than the horizontal force exerted by the man (when the object remains still). Most students of the experimental group seemed to have overcome this misconception as they mentioned that these two forces have equal values in all circumstances, as the force by the man becomes greater and greater, with the static friction getting a maximum value. On the contrary, no substantial improvement was observed at the control group – only one student of that group seemed to have overcome this misconception. What's more, the vast majority of the students of the experimental group seemed to have realized which factors influence (and which do not influence) the value of the kinetic friction. On the contrary, several students of the control group considered that the kinetic friction depends on the object's velocity.

A CSCL Environment for the teaching of Electric Circuits

Nektarios Mamalougos* and Stella Vosniadou, University of Athens, Greece

Theoretical Framework

Computer supported collaborative learning (CSCL) is one of the most significant innovations for the facilitation of conceptual change improvement in educational settings. Collaborative learning is an educational method with which students are encouraged to work together in learning of objectives. It is distinguished from the traditional model of "direct transfer" in which the teacher is supposed to be the sole distributor of knowledge and skills.

Learning in school requires the attention of students, observation, memorization, comprehension, and undertaking of responsibility for their learning. These cognitive processes are not possible without active attendance and entanglement of student. Teachers should help students to be active in class and to place objectives developing their natural disposal for investigation, for comprehension of new things and for learning.

Research has shown that social collaboration can improve students' performance, motivation with interesting social activities which help them to increase their school work. Students work more to improve quality of their produced work, when they know that other students will also see it.

Methodology

Subjects and procedure

The curriculum topics of the Physics course in 8th level were about electrical circuits. For 10 instructive hours, one experimental class (24 children) and three control classes (66 children) participated in this research which was held at the laboratories of informatics and physics of Kostea-Geitona private school, during April and May 2002. The experiment was part of the ICT European project ITCOLE (Innovative Technologies for Collaborative Learning Environments and Knowledge Building).

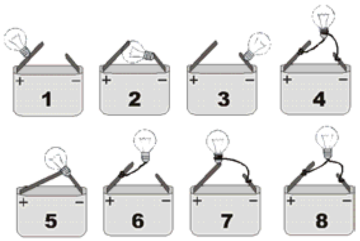
Description of the learning environment

In this research we combine: a learning environment for the teaching of Physics where emphasis is given to collaboration among students and to knowledge building, along with the Internet software 'Synergeia' which supports the collaborative building of common knowledge and the development of hypothesis testing. In CSCL environments, multimedia is used for the creation of a society of learners, who structure their knowledge together in groups: They build a learning frame, which include equipment and networks of information technology, as well as the teacher, the students and the corresponding instructive methodology.

Attention is paid to the functionality control of the pedagogic "tool", e.g. learning of natural sciences to be structured around the control of hypotheses. Regarding the didactical topics, the points of attention are: Building of electric circuits, modelling of electric current, predictions about the operation of circuit when local changes are applied and transformations of energy. Topics of the curriculum were also taught in the experimental class and in the control classes at the same period and for equal hours. Emphasis was paid on prediction and discussion.

Here we will report on two questions from the questionnaires, submitted to all students.

Question A. Selection of proper connection



We have a battery, a lamp and cables. We would like the lamp to turn on. If it turns on, which of the connections is/are correct?

Table I shows that students in experimental class gave more correct answers after the process, while before that, percentages between experimental and control classes were equivalent.

	Correct Answers	0	1	2	3
Experimental class	Before	38%	29%	29%	4%
	After	0%	13%	21%	67%
Control classes	Before	20%	62%	8%	11%
	After	14%	53%	11%	23%

Question B. Design of simple circuit in operation

We gathered from bibliography all preconceptions about the models of circuits in operation (monopolar, conflicts, weakening, partitioning); then we tried to pose a question, which is combined with a real experiment and an attempt to express all ideas and steps through *discussion working spaces* in software Synergeia.

We have a battery, a lamp and cables. (Inside the empty frame) Draw a connection, for the lamp to turn on. Also, draw with an arrow the direction of current through various parts of circuit.

The categorization of the answers we used is: [a] wrong circuit, wrong direction, [b] wrong circuit, correct direction, [c] correct circuit, wrong direction, [d] correct circuit and correct direction. We can clearly check out again the big differences and improvements that children of the experimental class (front surface) achieved.

	Circuit / Direction Models	a	b	c	d
Experimental class	Before	58%	13%	8%	21%
	After	4%	0%	25%	71%
Control classes	Before	43%	8%	20%	29%
	After	21%	9%	23%	47%

Conclusions

Results show a significant improvement of the answers of the students in the experimental class, compared to the one in the control classes; though a lot of attention was given to the same exactly subjects, within the same curriculum and timetable, by the teachers and their students. This indicates that the CSCL environment is more successful in producing conceptual change.

References

Bereiter, C. (2002). *Education and Mind in the Knowledge Age*. Mahwah NJ: Lawrence Erlbaum Associates

Brown, A. L. & Campione, J. C. (1994). Guided discovery in a community of learners. *In K. McGilly (Ed.) Classroom lessons: Integrating cognitive theory and class-room practice*. Cambridge, MA: MIT Press / Bradford Books

Scardamalia M. and Bereiter C. (1996), Chapter 10: "Computer Support for Knowledge-Building Communities", *in book "CSCL: Theory and Practice of an Emerging Paradigm*", edited by Timothy Koschmann, Southern Illinois University, 1996, Lawrence Erlbaum Associates Inc. Mahwah, New Jersey

Vosniadou, S., Kollias, V., Mamalougos, N., Vlassa, M. (1999): "Computer Supported Collaborative Learning and Conceptual Change in Science", CSCL 1999 Conference, Stanford University, USA

Vosniadou S. (2001), "How children learn", *Booklet, International Academy of Education*, International bureau of Education, UNESCO, 2001

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E., (2001) Designing learning environments to promote conceptual change in science. *Learning and Instruction*, Vol. 11, pp. 381–419.

B. Science Learning and Instruction

Chair: George Tsaparlis, University of Ioannina, Greece

Discussant: Lia Halkia , University of Athens, Greece

Conceptual Change in the Teaching and Learning of Solar Energy with 6th Grade Primary School Children in Greece

Nektarios Tsagliotis, University of Crete, Greece

Review of literature

Over the last twenty five years, many theoretical approaches on learners' conceptual change in science education have been developed (cf. Duit, 2002). In general terms, it appears that *"conceptual change denotes learning pathways from students' pre-instructional conceptions to the science conceptions to be learned"* (Duit, 1999). The classical approach of Posner *et al.* (1982) and its revised version (cf. Strike & Posner, 1992) is considered to support *a radical form* of conceptual change. Science educators faced several difficulties when they attempted to put into practice the four proposed conditions (*dissatisfaction, intelligibility, plausibility* and *fruitfulness*) in order to promote successful conceptual change. Strike & Posner (1992) criticise their theory for being too linear and overly rational, based on the assumption that learners have well-articulated conceptions or misconceptions for most science concepts.

Hewson & Hewson (1992) suggest that conceptual change can be seen through a change of *status,* which can be attributed to a particular conception and they distinguish between *conceptual capture* and *conceptual exchange* or *replacement*. Carey (1991) and Vosniadou (1994) appear to be considering a form of *weak restructuring* with elements of *enrichment* of pre-existing knowledge and *strong* or *radical restructuring* with elements of *revision* of prior knowledge and explanatory "framework theories" with the formation of "mental models" (Vosniadou, 1994), involving ontological and epistemological changes.

A radical notion of conceptual change is often related to restructuring, revision or accommodation of new conceptions to the learners existing systems of beliefs or knowledge. Nevertheless, as Duit & Treagust (2003) contend, there is no documentation of a case where a learner's conception could be completely extinguished or even replaced by a new idea. In this sense, conceptual change may not always be a radical, revolutionary shift in a learner's conceptions of a phenomenon. It can also be a gradual, evolutionary change in the way learners continuously enrich and reconstruct their conceptions, in an attempt to interpret the world in more advanced ways, within a context that includes situational and cultural factors facilitating this process (Vosniadou & Ioannides, 1998; Vosniadou *et al.*, 2001). Moreover, affective factors, such as the learners' goals, intentions, purposes, needs and expectations, appear to be equally important in a process of conceptual change (Sinatra & Pintrich, 2003).

Methodology and research design

From a practitioner-researcher's standpoint, aiming to provide an in-depth view of a particular situation (Schön, 1983), research has been carried out in an educational setting of a 6th grade of primary school with 35 children, divided into two classes. Two research episodes are involved in a broader inquiry framework, the first focusing on the study of aspects of conceptual change on teaching and learning about *mechanical energy* and the second about *solar energy*, whereas the latter has been extended to include *a science fair project*. Only the second research episode on solar energy is being reported here. Sixteen (16) children from the above mentioned educational setting, selected to be of mixed ability, have been interviewed before and after a teaching intervention, with the *Interview-About-Instances* technique (Gilbert *et al.*, 1985), using the same set of six interview cards. Follow up interviews were conducted three months after the completion of the research episode using another set of 4 interview cards, which depicted both similar but also differentiated instances from those of the first set.

In an attempt to achieve methodological triangulation, additional research methods have been used, within the same context. Thus, *concept cartoons* (Naylor & Keogh, 2000) have been used as a tool of formative assessment during the teaching interventions. *Concept maps* (Novak, 1998) on solar energy have been constructed by children, in an evolving, dynamic approach throughout the teaching intervention, whereas a total map was put together at the end of the teaching intervention, enhancing reflection in action (cf. MacAleese, 1998). Moreover, *children's written work* (Harlen, 2000) from particular question items and from report documents has been collected and is to be analysed accordingly.

Analysis and preliminary findings

The interviews have been fully transcribed and are being analysed in three levels. At first level the *Pre-Intervention Interviews* and the *Post-Intervention Interviews* are analysed separately, in order to elicit a variety of qualitatively different conceptions about the depicted instances before and after the teaching intervention on solar energy. At second level the elicited conceptions are to be compared within the context of each depicted instance, in order to identify conceptualisation differences, in an attempt to reveal the dynamics of conceptual change. At third level the conceptions of particular children-cases are considered across the interview cards, both in pre and post intervention interviews, in an attempt to obtain deeper insights in children's evolution of conceptions and conceptual change. The post-interviews, conducted 3 months later, will be considered separately and in combination with the 2nd and 3rd levels of analysis.

Preliminary findings indicate that *before the teaching intervention* solar energy appears to be conceived as "the energy coming from the sun", which "can do things for us". It can "give light" and "heat up things like water", or make "black things very hot" and perhaps "it can even cook food" or it can somehow "give electricity" or "electrical energy" with the solar cells. These appear to be seen initially as "properties" of solar energy, which happen or could happen anyhow due to "normal" every day processes (e.g. solar heaters *do* heat up water using the energy from the sun) or material properties (e.g. black things heat up very fast because that is what black things do or green houses are "hot boxes" because they heat up from the sun or "gain" high temperature), without discerning characteristics of *energy change* or *energy degradation*, within the context of depicted instances of the interview cards. *After the teaching intervention* conceptions about "energy change" appear to be discerned in the card-instances as solar-heat or solar-heat-kinetic (e.g. in the case of water heating up in the solar heaters) or solar-electric-kinetic-heat (e.g. in the case of the toy car moving with the solar cell). Furthermore, *energy degradation* is seen though "energy change to heat" conceptions due to "friction" and "crashes" or "fading" of energy, which "is put out of use" or is "incapacitated" (e.g. in the moving solar toys), but also as "heat that escapes" out of solar heaters, or solar cookers (e.g. pizza box solar cookers or more

advanced box solar cookers), which "needs to be taken care of", in order to construct more effective devices.

References

Carey, S. (1991) Knowledge acquisition: Enrichment or conceptual change? In Carey, S. & Gelman, E. (Eds.) *The epigenesis of mind*, Hillsdale, NJ, Erlbaum, pp. 257-291.

Duit, R. & Treagust D.F. (2003) Conceptual change: a powerful framework for improving science teaching and learning, *International Journal of Science Education*, Vol. 25(6), pp. 671-688.

Duit, R. (1999) Conceptual change approaches in science education. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 263–282). Amsterdam, NL: Pergamon.

Duit, R. (2002) *Bibliography STCSE: Students' and teachers' conceptions and science education*. Kiel, Germany: IPN – Leibniz Institute for Science Education (URL: < http: //www.ipn.uni-kiel.de/ >).

Gilbert, J.K., Watts, D.M. & Osborne, R.J. (1985) Eliciting Student Views using the Interview-About-Instances Technique. In West, L.H.T & Pines, A.L. (Eds.) *Cognitive Structure and Conceptual Change*, London: Academic Press, pp. 11-27.

Harlen, W. (2000) *The teaching of science in primary schools*, London: David Fulton Publishers.

Hewson, P. & Hewson, M. (1992) The status of students conceptions. In Duit, R., Goldberg, F. & Niedderer (Eds.) *Research in Physics Learning: Theoretical issues and empirical studies*, Kiel, Germany: Institute of Science Education, pp 59-73.

McAleese, R. (1998) The Knowledge Arena as an Extension to the Concept Map: Reflection in Action, *Interactive Learning Environments*, Vol.6(3), pp.251-272.

Naylor, S. & Keogh, B. (2000) *Concept cartoons in science education*. Sandbach: Millgate House Publishers.

Novak, J.D. (1998) Learning, Creating and Using Knowledge: Concept Maps™ as Facilitative Tools in Schools and Corporations, London: LEA Publishers.

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*, Vol. 66, No. 2, pp. 211-227.

Schön, D. (1983) *The reflective practitioner*, New York: Basic Books.

Sinatra, G. M., & Pintrich, P. R. (Eds.) (2003) *Intentional conceptual change*. Mahwah, NJ: Erlbaum.

Strike, K.A. & Posner, G.J. (1992) A revisionist theory of conceptual change. In Duschl, R. & Hamiltonn, R. (Eds.) *Philosophy of Science, Cognitive Psychology* *and Educational Theory and Practice*, Albany, N.Y., State University of New York Press, pp. 147-176.

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

Vosniadou, S., & Ioannides, C. (1998) From conceptual change to science education: a psychological point of view. *International Journal of Science Education*, 20, 1213–1230.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001) Designing learning environments to promote conceptual change in science. *Learning and Instruction*, Vol. 11, pp. 381–419.

Promoting Conceptual Change in Acid-Base Concept

Eren Ceylan*, Ömer Geban and Hamide Ertepinar, Middle East Technical University, Turkey

In this study, one of our aims was to determine high school students' misconceptions about acid-base chemistry.

For better understanding and meaningful learning, there is a need for finding ways to overcome misconceptions. One of the instructional methods can be used for this purpose is conceptual change approach. Posner et al. (1982) proposed two types of conceptual change, assimilation and accommodation. Assimilation describes the process where students use existing concepts to deal with new phenomena and accommodation describes when the student must replace or reorganize his concepts. They proposed four conditions necessary for conceptual change to occur: 1)There must be dissatisfaction with existing conceptions. 2) A new conception must be intelligible. 3) A new conception must appear initially plausible. 4)A new conception should suggest the possibility of a fruitful research program.

Many techniques based on the conceptual change approach help students to change their misconceptions. One of the most successful techniques to overcome students' misconceptions is the conceptual change texts or refutational texts (Dole & Niederhauser, 1990; Hydn & Alverman, 1986; Maria & Macginite, 1987). Conceptual change texts are texts that refuse commonly held naive concepts. They directly state that commonly held intuitive ideas do not explain certain phenomena, they explain the target scientific concept (Hydn et al., 1994).

Many researchers and educators have accepted that the students bring to classes their backgrounds, attitudes, abilities and experiences. These naive descriptive and explanatory preconceptions are often different in significant ways from scientists' views and they are remarkably resistant to change by traditional instructional methods. Therefore, in this study, researcher determined the effectiveness of a teaching strategy based on conceptual change approach (Posner et al., 1982) to dispel students' misconceptions about acid-base chemistry. The main aim of this

study is to investigate the contribution of conceptual change oriented lesson to high school students' understanding of acid-base concept.

In this study, the aim was to investigate the effect of conceptual change oriented lesson in understanding of acid- base concept.

Methodoly

Subject: In this study, 63 tenth grade students from two classes of a chemistry course taught by the same teacher were enrolled.

Instruments: Acid-Base Concepts Test developed by researchers was administered to all students in the study.

Treatment: In the study, there were two groups of students: Experimental group and control group. Experimental group was instructed by conceptual change texts through teacher lecture. Control group received traditionally designed chemistry instruction. Both groups were given Acid-Base Concepts Test as pre-test at the beginning of the study to determine whether there would be a significant difference between two groups. In the control group, the students were instructed only with traditionally designed chemistry instruction. During the classroom instruction, the teacher used lecture and discussion methods and solved algorithmic problems to teach acid-base concepts. Also, the students were provided with the worksheets. Each worksheet included mathematical and conceptual chemistry questions. The teacher acted as a facilitator and answered some questions and make suggestions when needed. Worksheets were corrected and scored and the students reviewed their responses after correction. Students in experimental group work with the conceptual change texts. Conceptual change texts were prepared by the researchers. They identified common misconceptions about subject matter and directly informed students that may posses such kind of misconceptions. They activated students' misconceptions by presenting simple qualitative examples that allow the misconceptions to be used to make a prediction about the situation and they presented the evidence that typical misconceptions are incorrect and provided a scientifically correct explanation of the situation. Six conceptual change texts were written concerning the following topics; the concept of acid-base, the properties of acid-base, the concept of pH and pOH, the strength of acid-base, hydrolysis, the neutralization reaction. At the end of the treatment, all students were administered Acid-Base Concepts Test.

Analysis

ANOVA was used to identify the effects of treatment on students' understanding of acid- base concepts.

Results

The results have indicated that there was a significant difference between two groups in terms of students' achievement in Acid-Base Concepts.). In the light of this result, it can be concluded that instruction based on conceptual change produced good results than traditionally based instruction in terms of achievement in Acid-Base Concepts.

Discussion

In this study, the Acid-Base Concepts Test was administered to all subjects both before and after treatment. There was no significant difference between the pre-test mean scores of the two groups. It pointed that both groups were equal in terms of achievement related to acid-base concepts before the treatment. The indication of their prior knowledge related to acid-base concept is important because it is important in the combination and construction of new knowledge into their existing cognitive structure. The scientific conceptions of acid and base were taught to groups of students using two different instructional strategies.

The conceptual change oriented instruction caused a significantly better acquisition of scientific conceptions and elimination of misconceptions than the traditionally designed chemistry instruction. The difference between learning activities provided in conceptual change oriented instruction and traditionally designed chemistry instruction may cause to difference in achievement of students in both groups. The conceptual change oriented instruction was designed to lead students from their prior knowledge or misconceptions to the scientific knowledge. The traditionally designed chemistry instruction followed the logical presentation of acid-base concepts usually seen in textbooks on chemistry.

References

Ausubel, D.P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.

Garnet, P. J. (1992). Conceptual difficulties experienced by senior high school students of electrochemistry. Electric circuits and oxidation reduction equations. *Journal of Research in Science Teaching*, 29(2), 121 - 142.

Geban, Ö., Aşkar, P. and Özkan, İ. (1992). Effects of computer simulated experiments and problem solving approaches on high school students. *Journal of Educational Research*, 86, 5 - 10.

Geban, Ö., Ertepınar, H., Yılmaz, G., Altın, A. ve Şahbaz, F. (1994). Bilgisayar destekli eğitimin öğrencilerin fen bilgisi başarılarına ve fen bilgisi ilgilerine etkisi. I. Ulusal Fen Bilimleri Eğitimi Sempozyumu: Bildiri Özetleri Kitabı, s: 1 - 2, 9 Eylül Üniversitesi, İzmir

Hewson, G. P., Hewson, W. P. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning, *Journal of Research in Science Teaching*, 20(8), 731 - 743.

Lee, O., Eichinger, C. D., Anderson, W. C., Berkhemier, D. G., Blakeslee, T. D. (1993). Changing middle school students' conceptions of matter and molecules. *Journal of Research in Science Teaching*, 30(3), 249 - 270.

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(2), 211 - 227.

Tyson, L. M., Venville, G. J., Harrison, A. G., Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom, *Science Education*, 81, 387 - 404.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science education. *The Science Teacher*, September, 53-57

Zoller, U. (1990). Students' misunderstanding and misconceptions in college freshman chemistry (general and organic). *Journal of Research in Science Teaching*, 27(10), 1053 - 1065.

Promoting Students' Attitudes toward Chemistry Using Instruction Based on Constructivist Approach

Esen Uzuntiryaki* and Ömer Geban, Middle East Technical University, Turkey

Introduction

In science education, attitude is one of the most important factors. It is an affective concept influencing one's construction of knowledge and action to something. Since attitude is essential for understanding students' science related behaviors, it should be defined carefully. Usually, attitude is confused with beliefs, interests or values. Although these terms are related, they are different. Beliefs provide a cognitive base for attitude; they are informational and factual. Interest represents one's willingness to respond something. Value concerns with the moral issues and is much more broader than attitude (Chiappetta and Koballa, 2002). Attitude can be defined as predispositions to respond positively or negatively to objects such as ideas, events, places or people. It covers enjoyment, like-dislike, interest, confidence, perception, value, and competence. It can be measured by using an instrument consisting of dimensions above, by interviews or through observations (Hill and Atwater, 1995).

Recent research studies have indicated that students' attitude toward science is strongly related to their achievement in science. (Harty, Beall and Scharmann, 1985; Simpson and Oliver, 1990; Lee and Burkam, 1996).. Attitude should also be considered as an outcome of science education. Nature of science instruction affects students' attitudes toward science. It was found that use of hands-on laboratory program improved students' attitudes toward science and enhanced their achievement (Freedman, 1997). Extracurricular science activities caused students to see science more enjoyable, more interesting, and more attractive (Maoz and Rishpon, 1990). Using technology also affects students' attitudes toward science. Geban, Aşkar and Özkan (1992) concluded that students had more positive attitudes toward chemistry when were instructed through computer simulations. Also, for biology, computer assisted instruction produced more positive attitudes (Soyibo and Hudson, 2000).

These studies have shown that students hold more positive attitudes toward science when they are actively involved in the learning process. Constructivist teaching strategies are based on students' ideas and allow them to construct meaning actively through experience. According to constructivist approach, knowledge cannot be transferred to the students from a teacher, instead students construct their own meanings from the words or visual images they hear or see through experience. Students actively built up knowledge and knowledge develops and continues to change with the activity of the student. Then learning occurs by changing and organizing cognitive structure (Driscoll, 1994). Yager (1991) proposed a constructivist teaching strategies as:

- Invitation: Ask questions, consider responses to questions, note unexpected phenomena, identify situations where student perceptions vary
- Exploration: Brainstorm possible alternatives, look for information, experiment with material, discuss solutions with others, engage in debate, analyze data
- Proposing explanations and solutions: Construct and explain a model, review and critique solutions, integrate a solution with existing knowledge and experiences.
- Taking action: Make decisions, apply knowledge and skills, share information, ask new questions

These steps involve active participation of students and thus promote student' attitudes.

In sum, as well as knowing the scientific phenomena, students should also have positive attitudes toward science in order to be successful. Since knowing about students' attitudes toward science provides some insight about students' actions in science, teachers should consider their students' attitude toward science during instruction.

Purpose

In this study, the aim was to investigate the effect of instruction based on constructivist approach on students' attitudes toward chemistry as a school subject.

Method

Sample: Forty-two ninth grade students taking chemistry class from the same teacher were enrolled in the study.

Instrument: Attitude Scale toward Chemistry developed by Geban et al. (1994) was administered to all students in the study.

Treatment: There were two groups of students. Groups were randomly assigned as experimental and control groups. Each group studied chemical bonding concepts

covered as a part of the regular classroom curriculum in the chemistry course. The topics covered were definition of a bond, formation of bonds, types of bonds (intermolecular and intramolecular), polarity and properties of bonds.

At the beginning of the treatment, both groups were administered Attitude Scale Toward Chemistry in order to determine whether there was a significant difference between two groups in terms of their attitudes.

Control group students were instructed with traditionally designed chemistry instruction whereas experimental group students were instructed by instruction based on constructivist approach. In the control group, the teacher used traditional approach, he used lecture and teacher directed discussion methods. In the experimental group, the teacher began the instruction by asking questions to activate students' prior knowledge and promote student-student interaction. Students were allowed to discuss the question in groups by using their knowledge related to atoms. During these discussions, they saw their own and others' thinking, shared their ideas, defended their ideas and reached a consensus. The teacher presented new concepts based on students' answers. In this way, the teacher had opportunity to see his students existing ideas and misconceptions. He used some analogies during instruction in order to make concepts concrete.

At the end of the treatment, all students were administered Attitude Scale toward Chemistry.

Analysis

Independent sample t-test was used to analyze the data obtained.

Results and Conclusion

The results have indicated that there was a significant difference between two groups in terms of students' attitude toward chemistry ($t=2{,}053; df=40; p<0{,}05$). Mean score of experimental group students (57,32) was higher than that of control group students (51,15). In the light of this result, it can be concluded that instruction based on constructivist approach produced more positive attitudes toward chemistry than traditionally designed chemistry instruction.

Educational Importance

One of the aims of science education is to make students understand scientific phenomena. Teachers should use effective teaching strategies for meaningful learning. From constructivist point of view, teaching should involve active participation of students in scientific activities and construction of meaning. Students should use their knowledge; they should apply their knowledge to new situations and daily life (Niedderer, 1987). Most of the students think that it is difficult to learn chemistry and they do not want to study. This study emphasizes the importance of existing cognitive structure and peer interaction in construction of knowledge related to chemical bonding concepts. In addition, students' attitudes should be considered during instruction. Attitude is an important variable not only for better understanding of students' achievement but also for understanding of retention, motivation and future career plans. This study indicated that using constructivist strategies caused students to have more positive attitudes toward chemistry. Active involvement of students in science activities and using of their prior knowledge help students develop more favorable feelings toward science. In science education, little research has been conducted to compare the effect of constructivist strategies on students' attitudes. This study differed from other studies in that it examined the effect of constructivist environment on students' attitudes toward chemistry.

References

Chiappetta, E. L. And Koballa, T. R. (2002). *Science Instruction in the Middle and Secondary Schools*. Merril Prentice Hall, Columbus, Ohio.

Driscoll, M. P., (1994). Psychology of Learning for Instruction. Allyn and Bacon: A Division of Paramount Publishing, Inc.

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

Geban, Ö., Aşkar, P. and Özkan, İ. (1992). Effects of computer simulations and problem-solving approaches on high school students. *Journal of Educational Research*, 86(1), 5-10.

Geban, Ö., Ertepınar, H., Yılmaz, G., Altın, A. ve Şahbaz, F. (1994). The effect of computer assisted instruction on students' achievement in science and attitudes toward science. First National science Education Symposium: Absracts, p.1-2, 9 Eylül University, İzmir, Turkey.

Harty, H., Beall, D. and Scharmann, L. (1985). Relationship between elementary school students' science achievement and their attitudes toward science, interest in science, reactive curiosity and scholastic aptitude. *School Science and Mathematics*, 85(6), 472-479.

Hill, G. D. and Atwater, M. M. (1995). Attitudes toward science of urban seventh grade life science students over time, and the relationship to future plans, family, teacher, curriculum, and school. *Urban Education*, 30(1), 71-94.

Lee, V. E. and Burkam, D. J. (1996). Gender differences in middle grade science achievement: Subject domain, ability and course emphasis. *Science Education*, 80, 613-650.

Maoz, N. And Rishpon, M. (1990). Attititudes towards school science: A comparison of participants and nonparticipants in extracurricular activities. *School Science and Mathematics*, 90(1), 13-22.

Niedderer, H. (1987). A teaching strategy based on students' alternative frameworks: Theoretical concepts and examples. In J. Novak (Ed.), Proceedings of the Second International Seminar on Misconceptions and Educational

Strategies in Science and Mathematics (Vol. II, pp. 360-367). Ithaca, NY: Cornell University.

Simpson, R. D. and Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education*, 74, 1-18.

Soyibo, K. and Hudson, A. (2000). Effects of computer-assısted ınstructıon (caı) on 11th graders' attıtudes to bıology and caı and understandıng of reproductıon ın plants and anımals. *Research in Science & Technological Education,* 18(2), 191-199.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science education. *The Science Teacher*, September, 53-57.

Qualitative Study of Conceptual Evolutions in the Context of Free Exploration in Physics at the Secondary Level

Patrice Potvin, Université du Québec à Montréal, Canada

The research deals with qualitative understanding of physics notions at the secondary level. It attempts to identify and to label, in the verbalizations of 12 to 16 year-old students, the tendencies that guide their cognitive itineraries through the exploration of problem-situations. The research explores the nature and the mathematical treatment of links that were spontaneously established by these subjects between the parameters of problem-situations in physics. The hypotheses of work were about models, conceptions and intuitive rules (or p-prims). These last objects are seen, in DiSessa's epistemological perspective, as a type of habit that influences the determination of links between the parameters of a problem. In other words, they coordinate logically and mathematically. The research tries to identify regularities in the use of conceptual and intuitive objects within cognitive itineraries. At the end, these regularities offer a fresh and new point of view about five well known and broadly accepted assumptions that can easily be found in the research literature:

- In the study of physics problems, conceptions can be used as a skeleton on which one can construct his comprehension or on which he can make it evolve; conceptions allows us to follow the cognitive itineraries of individuals.
- In the comprehensive structure of their holders, conceptions are strongly held objects and they can resist to all sorts of treatments and teaching strategies, sometimes even to strategies that seem to take them in account explicitly.
- Conceptions usually exist since a very long time in the cognitive structure of their holders and they are generally present before schooling. And so they will necessarily interfere –positively or negatively- with teaching.
- Conceptions can be considered as elements of comprehension. Proof is that some teaching initiatives that take them in account specifically sometimes work.

- From one person to another, conceptions show regularities in their form and in their use, thus they can be repertoired so that science teachers can use these repertoires and predict the reactions of their students and also they can prepare lessons that take them in account.

At the end of the research, all these five assumptions will be seriously challenged by our results.

Methodology is based on explicitation interviews. This is a special type of interview that tries to stick as close as possible to the spontaneous evocations of the subjects. It is through the analysis of the verbalisations describing these evocations that the interviewer can understand and acknowledge the existence of certain habits of thought. One of the most important principles of this type of interview is that the interviewer must never ask questions that begin by the word “why”. So the explicitation interview type is looking for descriptions of “what is going on in the head” of the subject when he explores the situations, instead of looking for justifications. Thus it is a technique that spares the interviewer to trigger conceptions artificially, because conceptions very much look like justifications. Instead, the goal is to obtain descriptions of what is evoked most spontaneously by our subjects.

Twenty students were invited to share their evocations as they explored the logics of our computerized situations. This microworld is programmed on the *Interactive Physics*™ software –a virtual laboratory- and is made of five different situations that involve Newton’s laws. An analysis of the twenty student’s verbalizations shows the existence of elements that play a part in modelisation and qualitative construction of comprehension as well as in its qualitative/quantitative articulation.

Results indicate important regularities in the cognitive itineraries of the subjects. The interpretation leads us to identify a coherent sequence in the use of conceptions, including important parts when conceptions are completely absent. Other parts of the sequence show that some evoked conceptions are fairly easily abandoned, since in others, conceptions are spontaneously and immediately constructed. These results tend to favour the hypothesis that conceptions are not so solid, and might also not be as old as we thought they would be. They also seem to be subordinated to other, more important constructive forces, such as the ones that are developed by authors interested in intuition in science such as DiSessa, Fischbein, Brown or Stavy. In this perspective, conceptions appear to be like the shadows in Plato's allegory of the cavern; they are essentially phenotypical. At the end, all five assertions that were presented above are challenged by the results of this research.

Implications of the research are, among others, at the praxic level; it becomes possible to imagine more effective sequences of learning and teaching in physics based on the consideration of intuitive rules instead of the consideration of conceptions and despite the implicit nature of these objects. This is a truly constructivist practice which establishes bridges between novice and expert knowledge. Finally, the research calls for a renovation of science education’s major paradigm -conceptual change- based on treatment objects other than conceptions themselves, more fundamental and based on intuition.

Prerequisites for the Conceptual Change of Key Concepts Essential for the Teaching of the Theory of Special Relativity"

Kyriaki Dimitriadi*, Lia Halkia and Constantine Skordoulis, University of Athens, Greece

Introduction

The Theory of Special Relativity (SR) is one of the foundations of Modern Physics. Many investigations have been carried out on how it can be approached by university students (Pietrocola and Zylbersztajn, 1999, Scherr, 2001, etc); whereas similar investigations in Secondary Education (S.E.) are limited. To teach SR, it is necessary to introduce students to the key-concepts of Relativity.

As Villani and Arruda (1998) maintain, the teaching of Relativity in S.E. aims at students’ awareness of the conceptual rupture between Newtonian and modern Physics. In order to achieve this, it is important to know the students’ difficulties in this subject. Furthermore, Vosniadou et al. (2001) suggest that students to construct their own knowledge need to solve complex problems; think about their ideas; listen to the ideas of others; thus assuming control of their learning.

Aims

The research focuses on concepts considered prerequisites for the understanding of the SR, and aims at the investigation of: the students’ difficulties in the concepts referring to: the relativity of motion, the maximum speed in nature the ways promoting conceptual change in these concepts.

Methodology of Research

The research instrument was a questionnaire consisting of 4 short stories. Each was based on a scenario concerning snapshots of everyday life. The persons involved in these stories supported alternative positions about the investigating concepts. Students were asked to express their ideas and provide appropriate arguments supporting them. The first three stories investigated the relativity of motion and the fourth, the possibility of a maximum speed existing in nature. The construction of the questionnaire was such that each of the three first short stories was built on an increasing complexity. The questions were based on the difficulties that students face in these concepts according to bibliography. (Panse et al. 1994 ; Scherr, 2001; Villani and Pacca, 1987).

The sample was 124 students of upper S.E. (10^{th}, 11^{th} and 12^{th} grades, aged 15-17). The students came from two secondary schools: one in Athens (the school associated with the Department of Education of the University of Athens), and the other on Samos (an island on the eastern borders of Greece).

The research was carried out in three phases.

The questionnaire was addressed to:

A) 114 students individually.

B) 10 students of 12th grade, who have chosen Science as their main subject, divided into two groups. Members of each group had to argue and decide the proper answer to the questions. The relevant discourse of the two groups was recorded, to register the arguments developed and the difficulties they face.

C) 5 students (10th grade) chosen among these students who had already answered the questionnaire. The criterion of their choice was the variety of ideas and the elaboration of the various arguments aimed to support their ideas, expressed in the first phase of the research. They were asked to discuss and argue about the positions provided in the stories. Their discussion was also recorded, to investigate whether they could change their ideas when confronting the argumentations of the others.

The analysis of the collected data was based on the content analysis (questionnaires) and on the discourse analysis (cassette recordings). The criterion of the above analysis was the recording of the students' ideas about the relevant phenomena and the kind of arguments they used.

Findings

A) The content analysis (1st phase) showed that students meet difficulties in grasping the relativity of motion and in using the frames of reference properly. Students' ability to use frames of reference as conceptual instruments in handling the relativity of motion decreases with the complexity of the conceptual load, which the elaboration of the story demands. They consider as "objective observer" either the stationary one, or the one who performs the prime action of the story. The answers of the majority of the students are mainly determined by their everyday experience and by common sense.

Furthermore, their answers to the fourth story reveal that most of the students believe that surpassing the speed of light is a technological matter.

Between the two schools and among the different grades, there was no statistical semantic difference.

B) The discourse analysis (2nd phase) showed that although the students refer to the concept of the frame of reference, they have difficulties in applying it especially in complex environments (e.g. when the problem demands the change of frame of reference). In many cases, their argumentations are characterized by their daily experience and by common sense too. In the fourth question about maximum speed in nature, the first group supported the idea that in the future the speed of light will be surpassed, whereas the second group couldn't come to a conclusion.

C) The discourse analysis (3rd phase) reveals the potential of the discourse among students. Thus, whereas initially three students out of five supported wrong ideas; finally the group moved to the correct ones. To this result, the role of one of the first two students seemed important, although he had a low profile, his effect on the other students being based on his ability to use strong arguments. In the short story concerning maximum speed, they didn't reach a conclusion, because they were influenced by science fiction and they digressed.

Outcomes

Students seem to face difficulties in dealing with relativity of motion, in using frames of reference and in realizing that the maximum speed in nature is the speed of light which is an intrinsic property of nature. Discussion seems to play an important role in negotiating their ideas, which indicates a possible contribution towards the conceptual change. Worth noticing is the fact that students had the opportunity (third phase) to reexamine the subject again. In this phase, the synthesis of the group is important (mixed ideas), which makes the first phase (the investigation of ideas) essential. The increasing complexity of the questions proved to be positive too, because students had the opportunity to think deeply on the subject and to elaborate their ideas in more complex situations. This is very important, because it reveals students' implicit conceptions, thus assisting them to understand complex subject matter, such as S.T.R. (Hewson, 1982).

References

Hewson, P., (1982), "A Case Study of Conceptual Change in Special Relativity: The Influence of Prior Knowledge in Learning", European Journal of Science Education, vol 4, pp 61-76.

Panse, S., Ramadas J. and Kumar A., (1994), "Alternative Conceptions in Galilean Relativity: frames or reference", International Journal of Science Education, vol 16, no1, 63-82..

Pietrocola, M. and Zylbersztajn, A., (1999), "The use of the Principle of Relativity in the interpretation of phenomena by undergraduate physics students", International Journal of Science Education, vol 21, no3, 261-276.

Scherr, R. E., (2001), "An Investigation of Student Understanding of Basic Concepts In Special Relativity", PHD Thesis.

Villani, A. and Arruda, S., (1998), "Special Theory of Relativity, Conceptual Change and History of Science", Science & Education 7, 85-100.

Villani, A. and Pacca, L., (1987), "Students' spontaneous ideas about the speed of Light", International Journal of Science Education, vol 9, no1, 55-66.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., Papademetriou, E., (2001), "Designing learning environments to promote conceptual change in science", Learning and Instruction 11, pp. 381-419

C. From Family to School Setting: Affective and Cognitive Schemata, Attachment Processes and (Meta)cognitive Skills Related to Emotional, Behavioral and Learning Difficulties in School Age Children

Chair: Ilias Kourkoutas, University of Crete, Greece

Discussant: Ilias Kourkoutas, University of Crete, Greece

'Inner Working Model' and Behavioral Pattern: An Ecological - Contextual Approach

Ilias Kourkoutas, University of Crete, Greece

"Inner working model", is a notion introduced by Bowlby, designated to describe the inner schemata that guide child's behavior and child's relational patterns. "Inner working model" is also considered to condense the cognitive and affective schemata that govern child's coping strategies. Additionally, we outline the key elements of attachment processes that are affect regulation, interpersonal understanding and communication, information processing and exploration strategies. "Ecology" refers to the interactional and relationship context of attachment, and to the dynamic equilibrium of attachment with a wider array of interpersonal processes in families.

We also refer to studies that stress the notion of intergenerational transmission of inner working models and behavioural patterns.

Family Bonds and Emotional - Behavioral Problems in the School Environment

E. Papadaki-Michailidi, University of Crete, Greece

Psychologists for many decades have concentrated their interest on family relationships. It is well known that individuals develop through their relationships with others, so child development can only be studied as a joint enterprise of the child with his \ her caretakers.

Parents provide the context in which children grow and form the primary and the most important emotional bonds of their lives. Inside their families children form their emotional world by learning how to relate to others, how to care for others and how to cope with frustration, disappointment and loss. Families also shape the social and cognitive skills of their children.

The particular paper stresses the importance of parent – child relationship and correlates parental failure with the problems school age children usually face. Finally different cases of parental failure will be presented through various drawings of children with emotional and behavioral problems.

Effects of Anxiety on the Cognitive Functioning: The Case of Pupils 11 - 12 Years Old During the Completion of a Cognitive Task

E. Vassilaki, University of Crete, Greece

The last few years there has been a turn in research interests towards the investigation of the interaction between the cognitive system and emotions. More specifically, a turn towards the examination of the cognitive dimension of anxiety.

Anxiety - inducing situations influence the performance indirectly by inhibiting the individual from using all available information for decision making. As a result the individual becomes susceptible to a larger number of mistakes. In other words, anxiety influences the active process of information. Until today three types of distraction in the cognitive responses have been proposed: worry, emotionality and interference, produced during the completion of the task. *Interference* refers to the individual's tendency to be distracted by irrelevant to the task parameters such us the inability to leave aside unsolved problems and thoughts that bother them.

Additionally, high levels of anxiety reduce the available capacity of working memory. The individual places a lot of resources in monitoring and attending of the environment and this inhibits the effectiveness of task elaboration. It's possible that this selective attentional bias reduces the capacity of working memory during the execution of a task.

Within this theoretical framework we examined the interference of anxiety during the completion of a cognitive task in school children aged 11 – 12 years old.

Emotional Schemata and Mental Representations Undermining Internalizing and Externalizing Disorders in School Age Children: Alternative Programs of Supportive Intervention

Ilias Kourkoutas, University of Crete, Greece

Emotional schemata and mental representations are complex psychic phenomena based on both, cognitive and emotional processes. There exist strong evidence supporting the relation between the quality of these schemata/representations and the development of emotional and behavioral disorders in school age children.

In our paper, we will also refer to emotional and cognitive characteristics underlying the major behavioral and emotional difficulties appearing in school age children. The way children and adolescents perceived themselves is an important factor of social and academic integration. Children and students who view themselves as masterful and valuable are more likely to adapt successfully to stressful situations in school settings, than are those who perceive themselves as unable to exercise any control to their environment. Additionally, high self-esteem and high sense of mastery have been shown to be related to effective personal efforts to overcome stressful situations and the tendency to use active strategies to cope with stress. We conclude by presenting the basic principles of alternative educational programs aiming to support positive emotional and cognitive changes in the inner representations of these children.

14.30 - 16.30: Symposia

A. Conceptual Change in Astronomy

Organizers: Irini Skopeliti and Stella Vosniadou, University of Athens, Greece

Chair: Stella Vosniadou, University of Athens, Greece

Discussant: William Brewer, University of Illinois at Urbana-Champaign, USA

During the last decade a great deal of research has been conducted to investigate conceptual change in observational astronomy. Researchers have looked into children's changing ideas about the shape of the earth, their explanations of the day/night cycle, the seasons, the phases of the moon, etc. Most of the results have shown that young children think of the earth as a flat, motionless, physical object with the solar objects located above its top.

In the present symposium we will present a series of papers that investigated further some of the theoretical and methodological issues concerning the process of conceptual change in astronomy. The first two studies examine the role of external models on children's ideas about the earth. The third paper presents a longitudinal investigation of the cosmologies of children from China and New Zealand. The fourth study investigates the representations of the earth by congenitally blind children, while the last presentation raises the question of whether young children who are exposed to science instruction understand that there are different possible explanations of physical phenomena, those that are closer to "appearance" and those that are closer to "reality".

Children's Understanding of Globes as Models of the Earth

Karin Ehrlén, Stockholm University, Sweden

This study was conducted to find out more about how children may understand globes as models of the earth. Models play an important part in scientific explanations and in science classes. Gilbert, Boulter and Rutherford (1998ab) called attention to the fact that through the use of models in education pupils may become involved in problems that concern not only what constitutes an explanation but also what models are about. As Driver, Guesne and Tiberghien (1985), among others, have pointed out, pupils may very well understand what they are taught in school in other ways than were intended by the teacher. This may also be the case

when the teacher uses models. On the other hand, Scoultz, Säljö & Wyndhamn (2001) maintain that, if children have a globe as an aid to their thinking, they will easily accept the scientific concept of the earth.

Extensive research in recent decades (e.g. Nussbaum, 1979; Vosniadou, 1994) indicates that children have difficulty accepting a scientific astronomical conception of the earth. According to Vosniadou (1994), children may form synthetic models using components taken both from the scientific model and from an initial model based on everyday experience of a flat earth. Halldén et al. (2002) argue instead that the problem for children is to find the right context for different pieces of information about the earth. Before they can do this children could be said to use undifferentiated concepts, or compounded models, of the earth.

To ascertain what role a globe may play in helping children to form concepts of the earth, we must first try to grasp how the children themselves understand the globe. A globe is intended to demonstrate a scientific view of the planet earth; what the present study shows, however, is that it also seems possible to combine the globe as model with children's various compounded models of the earth.

The researcher in the present study conducted interviews with eleven children aged six to eight. The interviews were 20 to 30 minutes in duration and a globe was present during the entire interview. The interviews took up the question of the relationship between the globe and the real earth. The methodological approach in the interviews was to focus more on the child's own interests in the discussion than on a predetermined set of questions.

Previous research (e.g. Halldén et al., 2002; Nussbaum, 1979; Vosniadou, 1994) has shown that it is not uncommon for children to believe that we live inside a spherical earth. Here two of the interviews in which the children talk about this view will be discussed. What these two children say gives an indication of how children who have a compounded model of the earth in mind may understand a globe. During the course of the interview the girl in the first example points to the countries displayed on the surface of the globe and says: 'But these are inside'. She makes this comment while discussing whether in her view the globe actually resembles the earth. She also remarks that people live inside the globe and that in there it looks just like what we see around us. How are we to understand this? It could be explained with the help of two distinctions made by Luquet (2001/1927). According to Luquet, in making drawings there are two ways in which a child might try to attain realism. When using intellectual realism, child tries to depict an object by showing important details of the object, whether these details can be seen or not. When using visual realism the child tries to depict an object as seen from one perspective. Even if visual realism is the most common way of depicting in our culture, Luquet indicated contexts where intellectual realism is the preferred method even among adults. Therefore, in Luquet's view, the two ways of representing should be seen as different conventions for depicting. Thus, in the first example where the girl says that the countries depicted on the surface of the globe are actually inside the real earth, we can understand this as indicating that she is applying intellectual realism in her understanding of the globe as a depiction. Understanding the globe in this way makes it possible for her to see the globe as a model of the earth even if the countries, which she believes are inside the globe, are shown on the surface of the model.

A second example taken from the interviews shows that it is possible for a child to believe that people live inside the earth, and yet to regard the globe as a visually realistic representation. The girl in this interview remarks that we and everything else that we can see are inside the globe. When asked if the earth looks like the globe in front of her, she replies that she doesn't know because she has never been outside the earth. She seems to look upon the globe as something that could be a visually realistic depiction of what can be seen from the outside. However, this is something that she has no experience of herself and thus is unable to comment on.

These two examples show that some children, when confronted with a globe during an interview, may try to incorporate the globe into their own compounded models of the earth. Thus a globe, which shows a scientific view of the planet earth, does not in itself provide children with this view of the earth. We need to find out, therefore, not only what conceptions children hold about the earth, but also what conceptions children hold about the materials we use when teaching or investigating children's conceptions about the earth.

References

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

Gilbert, J. K., Boulter, C. & Rutherford, M. (1998a) Models in explanation, Part 1: Horses for courses? *International Journal of Science Education*, Vol. 20, No 1, 83-97.

Gilbert, J. K., Boulter, C. & Rutherford, M. (1998b) Models in explanation, Part 2: Whose voice? Whose ears? *International Journal of Science Education*, Vol. 20, No 2, 187-203.

Halldén, O., Petersson, G., Scheja, M., Ehrlén, K., Haglund, L., Österlind, K. och Stenlund, A. (2002) Situating the question of conceptual change. In Limon & Mason. (Eds) *Reframing the Concept of Conceptual Change*. Nederländerna: Kluwer Academic Publishers.

Luquet, G.-H. (2001/1927) Children's Drawings. (Le Dessin Enfantin) Translated with an Introduction and Notes by Alan Costall. London: Free Association Books.

Nussbaum, J. (1979) Children's Conceptions of the Earth as a Cosmic Body: A Cross Age Study. *Science Education 63*. 83-93.

Schoultz, J., Säljö, R. & Wyndhamn, J. (2001) Heavenly Talk: Discourse, Artifacts, and Children's Understanding of Elementary Astronomy. *Human Development 44.* 103-118.

Vosniadou, S. (1994) Capturing and modeling the process of conceptual change. *Learning and Instruction*. Vol. 4, 1. 45-69.

How Cultural Artifacts Influence Children's Understanding of the Shape of the Earth

Irini Skopeliti* and Stella Vosniadou, University of Athens, Greece

In this experiment we investigated the effect of an external representation, the globe (which is the culturally accepted artifact representing the earth) on children's reasoning in elementary astronomy.

Twenty children from the 1st grade, and twenty two children from the 3rd grade were interviewed individually. At the first part of the interview the children were asked to make their own representations of the earth (i.e., drawings and play-dough models) and to indicate where people live on the earth using their model. At the second part of the interview the same children were presented with a globe and were told that the globe is the culturally accepted model of the earth. They were then asked to justify the differences between their own representations of the earth and the globe (if there were such differences), and to answer another set of questions regarding the shape of the earth and the areas where people live.

The results showed an increase in the frequency of scientifically correct responses for the older children and a decrease in alternative models of the earth. Most of the children who did not give spherical earth responses were found to be internally inconsistent. The results are interpreted as indicating that cultural artifacts are not transmitted directly but that the process of internalization is a constructive process during which the nature of the cultural artifacts may be distorted.

Cultural Mediation of Children's Cosmologies

Eric Blown* and Tom Bryce, University of Strathclyde, Scotland

Children in China and New Zealand observed the motion of the Earth and Sun, the phases of the Moon, the movement of clouds, and the changing seasons from their school playground in this longitudinal, cross-cultural investigation of children's cosmologies utilising Piagetian interviews. Nussbaum and Novak's original (1976) study in the USA predicted that the categories of cosmologies of the Earth which they discovered would be common to children of all cultures. This was followed by a series of mono-cultural and cross-cultural studies seeking to determine the scope and limits of children's astronomical concepts, particularly their cultural uniqueness or universality. From a cross-cultural perspective, the work of Mali and Howe (1979, 1980) in Nepal was of seminal importance. They found that traditional culture did not appear to influence children's science concepts (for example, the traditional Nepali belief in a flat earth supported by elephants). A number of researchers argued that further work was necessary in as many diverse cultures as possible to determine the scope of cultural mediation, with Brewer and Samarapungavan making the plea in 1991 that "…we need cross-cultural research that examines children's theories in societies that have not adopted the scientific view of the world". One major programme of research has been that of Vosniadou et al who looked at Samoa (Brewer, Herdrich & Vosniadou, 1987); Greece (Vosniadou & Brewer, 1990; Vosniadou, Archodidou, Kalogiannidou & Ioannides, 1996); India (Samarapungavan & Vosniadou, 1988; Samarapungavan, Vosniadou & Brewer, 1996); and American-Indian children (Diakidoy, Vosniadou & Hawks, 1997). The most significant findings were those from Samoa which showed distinct cultural variation with children modelling the earth as a torus or ring based on the traditional shape of Samoan villages.

In parallel with such investigations on children's cosmological concepts, the broader implications of the research have been realised, perhaps particularly the similarities between children's cosmological development and the historical development of scientific thought (cf. Kuhn's scientific revolutions) with radical restructuring characterising similarly profound changes in conceptual organisation (schema) in children (diSessa, 1982; McCloskey, 1983). Comparisons between conceptual change in adults and children was also highlighted by research into other forms of conceptual change known as the expert-novice shift, an example of weak restructuring (see Vosniadou & Brewer, 1987), in which experts have more complex and more abstract conceptual organisations than novices (see Chi, Feltovich & Glaser, 1981; Larkin, 1979, 1981). And it was hypothesised by Vosniadou & Brewer (1987) that the domain of children's cosmologies could provide evidence for and against conflicting theories of cognitive development and conceptual change - for example, between global restructuring and Piagetian theory where some psychological mechanism limits cognitive development in all domains; and, alternatively, domain-specific restructuring (including the weak and radical forms described above) where knowledge of a domain gained through experience and/or instruction can induce conceptual change. However, because of the need for any comprehensive theory of conceptual change to mirror scientific thought, the nature of which may itself be mediated by culture and gender, cross-cultural studies were essential to ascertain the universality of children's cosmological concepts and to gather evidence of the processes underlying conceptual change. New Zealand and China were selected for the present studies because of their entirely different language roots; their distinct astronomical heritages; and their manifestly divergent cultures. It was felt that by maximising cultural difference, any cultural mediation factors would be enhanced.

Methodology

The methodology was based on Piagetian interviews during which children observed the apparent motion of the Sun using a shadow stick, the motion and phases of the Moon, and other features of the Earth. These observations afforded conceptual sharing of ideas about the motion, shape, structure and nature of the

Earth, Sun and Moon; concepts of time including daytime, night-time; identity with and habitation of Earth; and gravity.

Participants

688 children (Age 2-18) participated including 129 boys and 113 girls from China, and 217 boys and 227 girls from New Zealand.

Research design

These studies were unique in four ways reflected in the research design. Firstly, unlike any previous studies in this field, they were based almost entirely on observation of astronomical/Earth science phenomena directly observable by children. Secondly, they were designed to be multimedia-multimodal affording children the opportunity to share their ideas in three different ways (verbal, drawing, and play-dough). The responses from each of these media were categorised using the same ordinal scale in each cosmological element so enabling triangulation of measurement of each concept, compensating for any inability to share meaning in a particular modality. Thirdly, the studies were planned as a longitudinal study (from 1987 to 1998 in New Zealand; and from 1994 to 2000 in China) using repeated Piagetian interviews. Allowance was made for an adequate final sample size; a control group design to measure factors such as the influence of being asked questions in an earlier survey; interview guides and categorisation schemes flexible enough to be valid for over a decade; data capable of rigorous statistical analysis. And fourthly, the studies compared the cosmologies of children from two cultures hitherto un-researched.

Results, discussion and conclusions

There was evidence of fundamental changes in conceptual schematic organisation akin to radical restructuring taking place over relatively long periods of time (e.g. from geocentric to heliocentric between 2-year surveys). However, some of the processes of conceptual change observed during interactive dialogue were dynamic in nature enabling images of alternative cosmologies (e.g. the dynamics of eclipses) to be compared in very short time periods. The evidence suggests that these rapid changes resulted in permanent schematic reorganisation. The evidence also indicated that primary age children could comprehend the rotation of the Earth on its axis, the revolution of the Earth about the Sun, the revolution of the moon about the Earth, and associated concepts of time based on spherical models of the Earth, Sun and Moon, provided that teachers used innovative methods of instruction based on observational astronomy. These studies have found little differences between the cultures ($p < .01$). Bearing in mind that China and New Zealand are very different cultures, this is a surprising result. However, as in Mali and Howe's (1979, 1980) studies, the present research has found that the most dominant cultural influence on children is that of school curricula reflecting the scientific world view.

The Development of Observational Astronomy in Blind Children

Kalliopi Ikospentaki* and Stella Vosniadou, University of Athens, Greece

The purpose of the present study is to investigate congenitally blind children's representations that fall into the field of observational astronomy. More specifically our interest is focused on congenitally blind children's ideas about the shape of the earth, the sun, the moon and the stars and on how they may explain phenomena like the gravity on the bottom of the spherical earth and the day/night cycle.

In prior research Vosniadou and her colleagues found that children construct initial representations of the physical world, which are influenced from their everyday experience. These representations may become an obstacle, when children try to understand the scientific explanations of phenomena that teachers present them. Assuming that the cause for the initial representations is the empirical, optical data which children get from the world that surrounds them, we presume that congenitally blind children won't have difficulties in understanding the scientific explanations.

In the present research twenty congenitally blind children participated. These children were students of the special primary school of the Centre of Education and Rehabilitation of Blind People in Athens. Their ages varied, but educationally they were grouped in the 1st and 3rd grade of primary school. Children were individually interviewed. They were asked questions concerning the shape of the earth, the sun, the moon and the stars and the explanation of the day/night cycle. They were also given play-dough in order to construct a model of each planet they were asked for.

Our results showed that blind children who attended the 1st grade constructed initial models of the earth and the other planets as well. Some 3rd grade students constructed alternative models of the earth and initial models of the other planets, although they had instructed the scientific theories that fall into this field. Generally the congenitally blind children's answers indicate a lack of variety, comparing them with the answers of sighted children of the same educational group. Possibly the verbal and haptic information, which blind children get from their surrounding are sufficient to influence them in a way to construct initial representations, which may hinder them in understanding the scientific explanations.

Distinguishing Among Scientific and Phenomenological Interpretations of the Physical World

Natassa Kyriakopoulou* and Stella Vosniadou, University of Athens, Greece

Research on the acquisition of knowledge about the physical world has shown that young children construct initial, naïve theories about the physical world that are fundamentally different from the scientific theories they later learn at school. Learning science can be conceptualized as a process of conceptual change in the

context of theory change. Do children have the metaconceptual awareness of this conceptual change and of the nature of the process of knowing?

In our research, this question has been conceptualized in terms of two closely related problems, the ontological problem of distinguishing between "reality" and "appearance" and the epistemological problem of understanding explicitly that there are different possible explanations of physical phenomena, those that are closer to "appearance" and those that are closer to "reality". In two experiments, 52 and 60 elementary school children (grades 1st, 3rd and 5th) respectively, were asked to distinguish between phenomenological and scientific representations of the shape of the earth and gravity, of the day/night cycle, of the planetary system and of the relative sizes of the earth, the sun and the moon.

The results showed that the solution of the ontological problem is a necessary but not sufficient condition for the solution of the epistemological problem. It appears that children start with the construction of phenomenological representations of the physical world that are gradually replaced with representations closer to the scientific ones. This change does not necessarily produce the understanding that the same phenomenon can be seen from two different perspectives. The epistemological problem of understanding the difference between the phenomenological and the scientific interpretation of a phenomenon appears later in development.

B. Cognitive Penetrability of Perception and Conceptual Change

Organizer: Athanassios Raftopoulos, University of Cyprus, Cyprus

Chair: Mark Rowlands, University of Exeter, UK

Discussant: Peter Machamer, University of Pittsburg, USA

Due to philosophical work, the thesis that perception is theory-laden was widely accepted. This was reinforced by psychological studies, which showed that cognition permeates perception. Neurophysiological research further corroborated this view by highlighting the existence of neural pathways that carry information from cognitive to perceptual centers in the brain. Conceptual change had played an important role in this affair, since the pioneer work was heavily influenced by studies of how cognitive change affects the way people reorganize the way they perceive, and cognize about, the world.

The issue has been revived by work suggesting that there may be a part of perception that is cognitively impenetrable. This work tried to explain away the psychological evidence supporting the theory-ladenness of perception, to account for the role of top-down neural pathways.

In this symposium we intend to bring forth the debate on this issue and relate it to current views on cognitive change. Brewer suggests that what we believe affects what we see and presents evidence to support this. Rowlands discusses the interrelation between action and perception and claims that this relation undermines any attempt to defend the cognitive impenetrability of perception. Raftopoulos sketches a dynamical view of conceptual change relates it to action and argues that the representational apparatus required to support this view of change is conceptually unmediated. Portides, finally, explores what the processes of construction of models in Nuclear physics can teach us about conceptual change. He argues that the idealisations that accompany each model are a determining factor to the conceptualisation of the nucleus. Since, changes in the idealisations determine changes in meaning, the reasons for changes in the concepts are to be found in the use of different idealising assumptions and hence that continuity of meaning is to be found in the continuity of the different idealisations.

Perception and Cognitive Penetrability

Mark Rowlands, University of Exeter, UK

A vehicle of visual perception is one or another sub-personal mechanism and/or process implemented in such a mechanism, where such mechanisms and processes allow (in part) an organism to visually perceive. At the level of vehicles of perception, it is fairly orthodox to suppose that the processes that begin with worldly impingements on the senses and culminate with a visually based judgment about the nature of that world admit of the following tripartite structuring:

Sensation: This consists in all processes leading up to the formation of the retinal image. This image, in itself, contains very little visual information. Indeed, the poverty of information is typically thought to render the retinal image cognitively useless.

Perception: The retinal image is gradually transformed along the visual pathways, by processes that essentially serve to structure, embroider and embellish the information contained in it. Construction of edges, boundaries, shapes, colors, and so on provides structures that are more suitable for subsequent processing by non-perceptual mechanisms.

Cognition: All subsequent processes fall under the category of cognition. Such processes are typically taken to include post-sensory operations concerned with recognition and categorization of objects and also purely semantic operations aimed at incorporating the resulting representations into the subject's psychological economy.

Given this tripartite distinction, I shall use the expression V-perception to denote the sub-personal mechanisms and processes that are standardly thought to operate subsequent to sensation and prior to cognition. I shall also talk of V-perceptual representations to denote the products of properly perceptual (as opposed to

sensational or cognitive) processes. And I shall talk of V-perceptual processing to denote the operations whereby the retinal image is transformed into a V-perceptual representation.

Orthodox accounts of V-perception are predicated on two assumptions that jointly delineate, at least in part, the logical space within which debates about the cognitive penetrability of such perception must, it is thought, be decided. We might mark the centrality of these assumptions to orthodox accounts by designating them framework assumptions. These are:

The Internality Assumption: V-perception is internal. V-perceptual processing begins with the retinal image and culminates in the production of a V-perceptual representation. Both image and resulting representation are internal to the perceiving organism where 'internal' means 'does not extend beyond the skin of'. Moreover, every process involved in transforming the retinal image into a V-perceptual representation is internal in the sense that it is implemented by, or realized in, structures and mechanisms that do not extend beyond the skin of the perceiving organism. It is true that the content carried by this V-perceptual representation may be individuation dependent on items outside of the organism – for example, those distal items ultimately responsible for the relevant impingements on the retina. Nevertheless, external individuation of the content of the V-perceptual representation does not entail external location of V-perceptual representation itself. And the V-perceptual representation is located inside its subject, even if the content of this representation is externally determined.

The Assumption of Genuine Duration: V-perception has genuine duration. V-perceptual processing begins at a determinate time, even if this time is difficult to discern. It begins when the relevant processes begin their job of transforming the retinal image into a V-perceptual representation. It also ends at a determinate time: when this transformation process is complete and the appropriate V-perceptual representation has been *activated*. In addition, V-perceptual processing has no intermittent lacunas. This latter claim requires some care. The idea is that the *tokening* of V-perceptual processing operations is not the sort of thing that can be halted and then restarted *without becoming a distinct token*. That is, in such an event we would have a new, distinct, token processing operation, merely one that begins with the same – or similar – retinal image and that culminates in a V-perceptual representation of the same type as that in which the original token processes would have culminated were they to have been completed. The claim that V-perceptual processing has a determinate beginning and end, and no intermittent lacunas, is the claim that such processing has *genuine duration*.

I shall argue that both of these framework assumptions are false. The issue is clouded because it is always possible to identify some component of V-perception that does satisfy the assumptions. However, any attempt to stipulate that this component alone constitutes V-perception would, I shall argue, be arbitrary and unrealistic. The reason for this turns on the nature of C-perception. C-perception, I shall argue, is often extended in two senses: (1) extended out into the world, and (2) extended through time. Because of the extended character of C-perception, I shall argue, we must reject the framework assumptions for V-perception. V-perceptual processing does not consist in purely internal operations, and it does not, typically, possess genuine duration. The rejection of the framework assumptions for V-perception, I shall argue further, entails that recent attempts to safeguard the cognitive impenetrability of perception fail.

Top-Down and Bottom-Up Influences on Observation: Evidence from Cognitive Psychology and the History of Science

William Brewer, University of Illinois at Urbana-Champaign, USA

The hypothesis that theories might influence observation was proposed in the important early work of Hanson (1958) and Kuhn (1962). Recently Fodor (1984, 1988) has argued that perception is not cognitively penetrable, while Churchland (1979, 1988) has argued for a strong form of theory-ladenness. This issue has led to very heated debate in the philosophy of science because many scholars have felt that if observation is theory- laden there can be no neutral observation data, and this leads to epistemological relativism. The outcome of this debate is directly relevant to the issue of conceptual change. If perception is completely theory-laden then there is little likelihood that experimental demonstrations or descriptions of observational data can be used to encourage conceptual change. I wish to criticize two assumptions that have been made in this debate.

Overemphasis on Visual Perception: First, I think that the emphasis on visual perception and scientific observation reflects a narrowing of focus that began in philosophy with the British Empiricists, became very strong with the work of the Logical Positivists, continued undiminished with the anti-Positivist work of Kuhn and Hanson, and remains strong today in the debate between Fodor and Churchland. However, a number of scholars (Bogen and Woodward,1992) have recently pointed out that data in modern science are typically not based on the perceptual experience of the scientist.

Ecological Validity: Second I argue that an analysis of the issues of the theory-laden debate in terms of the ecological validity of the evidence shows that the only experimental literatures in the area of perception that are relevant to the philosophy of science are those that deal with end products of the perception of objects in the world since that is what scientists are using to carry out their investigations. Fodor (1983) and Raftopoulos (2001a, 2001b) consider the possibility that there is a point in the visual process that is not cognitively penetrable. I think the use of this type of naturalistic evidence is completely undercut by the ecological validity argument. For the relevant issues in the philosophy of science, we do not care about the path leading up to the final perceptions of the scientist; we are only interested in the final product of the perceptual process. I feel that for a valid naturalized philosophy of science one

must use the empirical studies that are appropriate for the task one is trying to understand.

Top-down Bottom Up Approach. On the direct issue of the experimental evidence for the theory-ladenness of perception I wish to argue for an intermediate view in which perception/observation is conceived as the product of both bottom-up and top-down factors. This view allows one to accept top-down effects without sliding down the slope into relativism.

Evidence for Top-down Influences on Perception: A number of studies have been carried out on the impact of top-down information on the perception of ambiguous figures (Goolkasian, 1987; Leeper, 1935). These studies presented observers with an unambiguous version of an ambiguous figure (such as the Old Woman/Young Woman) and then later showed the observers the ambiguous form. This type of top-down information has an enormous impact on what the observers see when presented with the ambiguous picture. Essentially all of the observers who had previously seen an unambiguous picture of an Old Woman saw the ambiguous figure as an Old Woman and essentially all of the observers who had previously seen an unambiguous picture of a Young Woman saw the ambiguous figure as a Young Woman. This task is not one of conceptual inference--each of two alternate forms of the ambiguous figure gives rise to a qualitatively different perceptual experience. Notice that this experimental situation is analogous to a scientist who develops a visual skill through practice at looking at a particular class of objects through a microscope or from past experience in scanning pictures from a bubble chamber.

It seems to me that these studies of ambiguous figures are strong evidence for top-down influences on perception. The experimental tasks used in these studies do not easily allow Fodor to escape by interpreting the effects as merely an inference, since the observers in these experiments report qualitatively different perceptual experiences when they see one version of the figure or the other.

Top-down Factors and Instruction. Chinn and Malhotra (2002) assessed 4th grade children's naïve theories about falling bodies (i.e., does a heavier rock fall faster than a lighter rock). After finding out what the children believed, they carried out the Galilean experiment in front of the children by dropping two rocks (from a chair, not the Tower of Pisa) and letting the children judge if the rocks hit the floor simultaneously or if one hit before the other. In the actual conditions under which the experiment was carried out, the outcome was difficult to see. Chinn and Malhotra found that 72% of the children who held the theory that heavy and light rocks fall at the same rate, observed the rocks to hit at the same time, while only 25% of the children who held the theory that heavy rocks fall faster, observed the rocks to hit at the same time. This study suggests that in order to facilitate conceptual change observational evidence must be very clear and explicit in order to override possible top-down effects.

Conclusions

Many philosophers of science from the time of the Logical Positivists have wanted to show that there was a hard rock of theory-neutral perception that could be used as the foundation for objective scientific knowledge. I think the evidence from cognitive psychology shows that this hope was not to be. However I think the evidence for top-down influences in the perceptual process does not have the grave epistemological consequences that many thought it would have. The examples of hallucinations and dreams show that perception can occur through totally top-down influences. However, in the usual case, bottom-up factors are the overwhelming influences on what we perceive. Examination of the experiments that found strong top-down effects on perception show that these effects are strongest when the bottom-up effects are the weakest--for example, when the perceptual information is degraded or ambiguous. The literature shows that strong, clear stimuli provide powerful bottom-up constraints on perception.

What Can We Learn about Conceptual Change by Studying the Evolutionary History of Scientific Models?

Demitris Portides, University of Cyprus, Cyprus

It is customary among philosophers of science when attempting to understand change in the meaning of the vocabulary of the sciences, and to explore the philosophical consequences of such change, to focus on the inter-theoretic (*vis-à-vis* the intra-theoretic) character of conceptual change. This practice, stemming I believe from the work of Kuhn and Feyerabend, often explores how the meaning of terms changes as we shift from one paradigm to another. Feyerabend's much discussed critique of the logical positivist view of science and in particular his critique of the 'development of theories by reduction' and on the 'covering law model of explanation', led him to the theses that neither meaning invariance nor the intimately related notion of theory consistency, characterize actual science and scientific progress. Both the 'development of theories by reduction' and the 'covering law model of explanation' were criticised in their capacity as views by which to relate scientific concepts inter-theoretically (that is, between distinct theories). Hence through Feyerabend's critique of logical positivism the character of conceptual change and the notion of incommensurability of meaning were tied up with inter-theoretic usage, consequently its significance was much amplified and thus led to relativist programs.

In this paper I argue that we can learn much about conceptual change by studying scientific progress intra-theoretically (that is, within a specific research program). Furthermore, that intra-theoretic scrutiny leads to the observation that conceptual change is not only frequently present in scientific inquiry, but that it plays a crucial role in scientific theorizing, that is, that it is intimately connected to the processes of construction of scientific models and scientific concepts. The study of nuclear model construction in particular teaches us that without conceptual change

scientific progress is impossible. However, we also learn, from such a study, that the character of conceptual change is not such as to sanction the thesis of incommensurability of meaning.

The research program that aims to understand the structure of the nucleus is philosophically interesting due to the fact that it is one of the few areas of physics that is not theory-driven; it is phenomenological, as physicists would say. The primary concept in this research program is that of the 'nuclear structure' which, after Heisenberg proposed the proton-neutron hypothesis, has developed through two stages.

In the first stage, two conflicting hypotheses coexist and give rise to two categories of nuclear models. In accord with the first hypothesis the nucleus is assumed as a collection of closely coupled particles and the models developed in this category account only for collective modes of nuclear motion, ignoring any plausible relative motion between the nucleons. In accord with the second hypothesis the nucleons are assumed to move in rather independent ways in an average nuclear field and the models developed in this category account for nuclear motion only as an aggregate of independent nucleon motion. Conceiving the nucleus in one of the two ways seemed, in the early stages of these developments, incompatible with the other. It gradually became apparent however, through the accumulation of experimental data, that the two were not only physically compatible but that they both contributed to our understanding of the nucleus. The primary reason being that the two categories of models each explained-well phenomena related to the nucleus that the other category failed to explain. Models of the first category, for instance, explain-well the phenomenon of nuclear fission and the electric quadrupole moments of the nuclei, whereas those of the second category explain-well the 'magic numbers' of the nuclei. The constant interplay between the processes of model-construction and the explanatory and predictive successes and failures of the resulting models is evidently operative, in this first stage of development of the nuclear research program, in shaping our concept of the nucleus.

The second stage consists in the synthesis of all the preceding results and the acquired knowledge about the nucleus, into one, more or less, all-inclusive model. This model, which came to be called the *unified model* of nuclear structure, is based on a rather complex hypothesis about the nucleus, which asserts that: the nucleus is a complex system of a collection of particles that exhibit some form of independent nucleon motion, but that this motion is constrained by a slow collective motion of a core of nucleons, and that the two modes of motion interact with each other, and furthermore that the collective mode of motion is constituted by three distinct kinds of motion (vibration, rotation and giant resonance), two of which demonstrate an interaction mode. Despite the fact that aspects of both previous hypotheses are present in the unified model, the unified model itself is the result of a conceptual framework which is, I argue, distinct from its predecessors. Some important questions that arise are "what kind of conceptual change is present in this scientific episode?", "what factors instigate this conceptual change?", "is the conceptual change such as to sanction the thesis of incommensurability?" etc.

I address these questions by examining the processes of construction of the nuclear models in relation to concept formation and meaning change. The processes of model construction are characterized by 'idealization' and 'abstraction', and my argument relies heavily on the view that the kinds of idealizations and abstractions involved cannot be explicated entirely by appeal to mathematical considerations. The idealizations we encounter are related at each stage to our conceptualization of the nuclear structure; they are, one could claim, the manifestation of our conception of the nucleus. The idealizing assumptions present in the models of the first stage are of a different kind from those present in models of the second stage. The first are highly abstract, whereas the second are relatively concrete, as it may be discerned from the concrete hypothesis underlying the unified model. I attribute this difference to the evolutionary history of the nuclear models. By this I mean the explanatory and predictive successes and failures of past models that shape the idealizations that are imposed on their descendants. Thus concepts may change, within the nuclear research program, but they are always subject to the particular idealizations involved. For instance, concepts that may seem different may be different versions of the same at different levels of idealization and abstraction. Through this exploration I attempt to establish that continuity of the idealizing assumptions determines continuity of meaning of the terms.

Conceptual Change and Action: A Case for the Cognitive Impenetrability of Perception

Athanassios Raftopoulos, University of Cyprus, Cyprus

I sketch a dynamical view of conceptual change, relate it to the interaction between agents and their environment, and argue that the representational apparatus required to support this view of change is retrieved in conceptually unmediated ways; it is the outcome of cognitively impenetrable perceptual mechanisms.

According to the dynamic view, change is an emerging property of the natural dynamics of a system that is soft-assembled from constituents, including the environment, that interact non-linearly. Change lies in the interlocking of multiple context-dependent processes. Recurrent neural networks, cascade correlation networks and Hopfield nets can be construed in a dynamical way; they can be described by means of the evolution of the activation values of their units over time.

The number of units of the network determines the number of dimensions of the state-space associated with the system. Their activation values constitute the actual position in the state-space of the system. The activation values are the variables of the dynamical system and their temporal variation constitutes the internal dynamics of the system. The behavior of the system, evolves as a result of the synergies

among the architecture of the network, the input it receives, and the previous activity of the network, under the control of the learning dynamics.

The activation states in which a network may settle into are the attractors of the system. These are the regions in state-space toward which the system evolves in time. The points in state-space from which the system evolves toward a certain attractor lie in the basin of attraction of this attractor. Cognitive change is viewed as the process of the appearance of new basins of attraction and/or attractors. In dynamical connectionism cognitive change is regarded as the individual's actual path through the space of possible synaptic configurations.

The classical approach to change is based on the conception of a cognizer who receives input, builds internal representations, processes these representations, and acts on the environment. Cognizer and environment form a system of two independent entities that interact. According to the dynamical approach, cognizers and environment form an entangled or intertwined, soft-assembled, system. In the classical frame, we store concepts, which are context independent entities that are activated each time one encounters a token of the type they stand for. Since the environment is an entangled part of the whole organism-and-environment, the behavior of an organism can be properly understood only in a specific context. The context becomes a part of the problem solving activity, and it is not just the space within which problem solving takes place. This is the contextualist or situated approach to cognition. A concept is no longer a static context independent entity in the mind, but it is more proper to view concepts as processes that involve interplay between the properties of the organism and the context. Conceptual knowledge is not a description of a category that functions as a detached database. It is the ability to construct situated conceptualizations of the category. Thus, the concept is necessarily characterized by a certain variation. Thus, there may not be a discrete entity or event that constitutes a concept.

The concepts "attractor" and "basin of attraction" suggest a way of simulating the classical notion of symbol. The attractor basins might be construed to have symbolic-like properties, in that different inputs that fall within the same attractor basin are pulled toward the same attractor (or cognitive state) of the system. Thus, various inputs (tokens) give rise to the same stable point of attraction, the attractor (type), which offers a dynamical analog of the classical symbol. The dynamical "symbols", are dynamic and fluid rather than static and context independent. As the network learns, the connection strengths continuously change. As the network changes, attractors change and their activations covary with the context.

The role of action on the environment becomes predominant; cognition itself is viewed as emerging from this interaction. A number of philosophers argue that any attempt to explain conceptual content and solve the grounding problem should start by analyzing what transpires at the basic level of on-line interactions. It seems natural to inquire as to the representations that subserve this interaction. In addition to the vision that leads to the apprehension of our world, there is vision for action. Neuroscientific evidence supports the existence of a "weak" nonsemantic kind of object representation that precedes other semantic representations of the same object. There is evidence that there exist in the cortex two or three visual streams, which serve roughly two different functions. The first is the dorsal system that utilizes visual information for guidance of action in one's environment. For that it needs information about the dimensions of objects in body–centered terms. It uses viewer–centered structured representations of surfaces of objects, and employs them to individuate, index, and track objects. The second is the ventral system that uses visual information for knowing one's environment, that is, for identifying, and recognizing objects.

The dorsal system processes spatial and motion information, information regarding size and shape, and information regarding the affordances of objects in a body–centered frame of reference. The information is retrieved from the scene directly by the low and mid–level vision, without recourse to any higher processing. Semantics do not affect these processes and they do not affect the on–line control of action.

The representations of objects that are used by the ventral system are richer. In addition to spatial information and information about size and shape, which is now cast in an object–centered reference framework, they also contain nonspatial and semantic information (about fragility, temperature, function, color, weight, etc.) This requires reference to previously stored knowledge about specific objects. The representations are conceptually mediated, since they are influenced by top–down semantic inferences.

There is independent evidence that the weak representations precede the semantic representations. Research on object–centered attention suggests that the representations of objects based on spatiotemporal, size, and viewer–centered shape information, precede and often override those based on featural information. Spatial, size and shape information is computed faster than the nonspatial information and the representations built in the dorsal system precede those of the ventral system.

The studies on vision for action and the studies of object–centered attention suggest that when viewing a scene, one builds first an object representation that contains only spatiotemporal, size, and viewer-centered shape information, which is used to individuate and index objects. This content is retrieved in conceptually unmediated ways from a scene; it is the outcome of a cognitively impenetrable perceptual mechanism.

Participants' Index

Participants' List

Ahtee, Maija; Department of Teacher Education, University of Helsinki, Finland. ahtee@edu.jyu.fi

Aidinis, Athanasios; Department of Primary Education, School of Education, Aristotle University of Thessaloniki, Greece. aaidinis@eled.auth.gr

Akpinar, Ercan; Department of Primary Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Alexander, Patricia; University of Maryland, USA. pa34@umail.umd.edu

Anapolitanos, Dionysios; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. danapol@phs.uoa.gr

Antonopoulos, Ioannis; Historical Researcher, Greece.

Arabatzis, Theodoros; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. tarabatz@phs.uoa.gr

Avraamidou, Lucy; Department of Education and Professional Studies, King's College London, UK. lucy.avraamidou@kcl.ac.uk

Balim, Gunay; Department of Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey. agunay.balim@deu.edu.tr

Baltas, Aristides; National Technical University of Athens, Greece. abaltas@central.ntua.gr

Biza, Irene; Department of Mathematics, National and Kapodistrian University of Athens, Greece. empiza@sch.gr

Blown, Eric; Faculty of Education, University of Strathclyde, Scotland, UK. eric.blown@strath.ac.uk

Brewer, William; University of Illinois at Urbana-Champaign, USA. wbrewer@uiuc.edu

Brodeur, Monique; Pavillon de l'Éducation, Université du Québec à Montréal, Canada. brodeur.monique@uqam.ca

Bryce, Tom; Faculty of Education, University of Strathclyde, Scotland, UK. t.g.k.bryce@strath.ac.uk

Butler, Jim; School of Education, The University of Queensland, Australia. j.butler@uq.edu.au

Caravita, Silvia; Instituto di Scienze e Technologie della Cognizione, CNR, Rome, Italy. caravita@www.ip.rm.cnr.it

Carretero, Mario; Department of Psicología Basica, Universidad Autónoma de Madrid, Spain. mario.carretero@uam.es

Çetin, Gülcan; Department of Secondary Science and Mathematics Education, Faculty of Education, Middle East Technical University, Ankara and Department of Biology Education, Necatibey Education Faculty, Balıkesir University,Turkey. gcetin@metu.edu.tr, gulcan_cetin@hotmail.com

Ceylan, Eren; Middle East Technical University, Ankara, Turkey. eceylan@metu.edu.tr

Christiannides, Ioannis; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. ichrist@cc.uoa.gr

Christodoulou, Spyros; School of Pedagogical and Technological Education, Athens, Greece.

Christou, Konstantinos; Graduate Program in Cognitive Science, National and Kapodistrian University of Athens. kochrist@phs.uoa.gr

Chronaki, Anna; Department of Early Childhood Education, School of Human Sciences, University of Thessaly, Greece. chronaki@uth.gr

Chryssanthopoulou, Katerina; Graduate Program in Cognitive Science, National and Kapodistrian University of Athens. katerina_chr@yahoo.com

Clement, John; Scientific Reasoning Research Institute and School of Education, University of Massachusetts, Amherst, USA. clement@srri.umass.edu

De Bock, Dirk ; European Institute for Higher Education, Brussels, Belgium and Center for Instructional Psychology and Technology, University of Leuven, Belgium.

Deaudelin, Colette; Université de Sherbrooke, Canada. colette.deaudelin@sympatico.ca

Delikanis, Panagiotis; Department of Mathematics, National and Kapodistrian University of Athens, Greece. pdelkan@math.uoa.gr

Demerouti, Margarita; National and Kapodistrian University of Athens, Greece.

Demetriou, Andreas; University of Cyprus, Cyprus. ademetriou@ucy.ac.cy

Desli, Despina; School of Education Sciences in Pre-School Age, Faculty of Education Sciences, Democritus University of Thrace, Greece. ddesli@psed.duth.gr

Di Nur, Nirit; Department of Education in Technology and Science, Technion – IIT, Haifa, Israel.

Dimitriadi, Kyriaki ; Department of Primary Education, National and Kapodistrian University of Athens, Greece. kdimitr@primedu.uoa.gr

Duschl, Richard; Graduate School of Education, Department of Learning & Teaching, Rutgers University, New Jersey, USA. rduschl@rci.rutgers.edu

Dussault, Marc; Université du Québec à Trois-Rivières, Canada.

Ehrlen, Karin; Department of Education, Stockholm University, Sweden. karin.ehrlen@ped.su.se

Ekici, Celil; Middle East Technical University, Ankara, Turkey.

Entwistle, Noel; University of Edinburgh, UK. noel_entwistle@education.ed.ac.uk

Ergin, Omer; Department of Primary Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Ertepinar, Hamide; Department of Elementary Science and Mathematics Education, Faculty of Education, Middle East Technical University, Ankara, Turkey.

Euaggelou, Euthimios; School of Pedagogical and Technological Education, Athens, Greece.

Filios, Andronikos; School of Pedagogical and Technological Education, Athens, Greece. afilios@aspete.gr

Gavroglou, Konstantinos; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. kgavro@cc.uoa.gr

Geban, Ömer; Department of Secondary Science and Mathematics Education, Faculty of Education, Middle East Technical University, Ankara, Turkey.

Geyer, Claudia; Faculty of Social Sciences (SOWI), University of the GAF Munich, Germany.

Gikopoulou, Rania; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. rgicop@yahoo.com

Goclowska, Barbara; Maria Curie Sklodowska University, Lublin, Poland. gocbar@tytan.umcs.lublin.pl

Gorodetsky, Malka; Department of Education, Ben Gurion University, Beer Sheva, Israel.

Gosselin, Catherine; Université du Québec à Montréal, Canada.

Haerle, Florian; Carl von Ossietzky Universtität Oldenburg, Germany. florian.haerle@mail.uni-oldenburg.de

Hagai, Ety; Department of Education, Ben Gurion University, Beer Sheva, Israel.

Haglund, Liza; Department of Education, Stockholm University, Stockholm, Sweden.

Hakkarainen, Olavi; Department of Physics, University of Jyväskylä, Finland.

Halkia, Lia; Department of Primary Education, National and Kapodistrian University of Athens, Greece. kxalkia@primedu.uoa.gr

Halldén, Ola; Department of Education, Stockholm university, Stockholm Sweden. ola.hallden@ped.su.se

Hessels, An; Center for Instructional Psychology and Technology, University of Leuven, Belgium.

Hoddeson, Lillian; University of Illinois at Urbana-Champaign, USA. hoddeson@uiuc.edu

Honkela, Timo; Neural Networks Research Center, Helsinki University of Technology, Finland. timo.honkela@hut.fi

Ikospentaki, Kalliopi; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. ikopopi@hotmail.com

Janssens, Dirk ; Department of Mathematics, University of Leuven, Belgium.

Kalouri, Ourania; School of Pedagogical and Technological Education, Athens, Greece. rkalouri@otenet.gr

Kamilatos, Charalambos; Secondary Education, Greece. chdkam@hotmail.com

Kangassalo, Marjatta; University of Tampere, Finland.

Karasavvidis, Ilias; Department of Primary Education, School of Education, University of Crete, Greece. ikaras@phl.uoc.gr

Keiny, Shoshana; Department of Education, Ben Gurion University, Beer Sheva, Israel. shoshk@bgumail.bgu.ac.il

Kindi, Vassiliki; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. vkindi@cc.uoa.gr

Kleeman, Sara; Oranim, Academic College of Education, Israel. klee1982@012.net.il

Kokkotas, Panagiotis; Pedagogical Department of Primary Education, National and Kapodistrian University of Athens, Greece. kokkotas@primedu.uoa.gr

Kollias, Vassilis; Department of Primary Education, University of Thessaly, Volos, Greece. vkollias@cc.uoa.gr

Korre, Irini; School of Pedagogical and Technological Education, Athens, Greece. sklirakis@mland.gr

Koschmann, Timothy; Department of Medical Education, Southern Illinois University, USA. tkoschmann@siumed.edu

Koukoutsakis, Antonis; Cognitive Science and Educational Technology Lab, National and Kapodistrian University of Athens, Greece. antkouk@phs.uoa.gr

Koulianou, Maria; Cognitive Science and Educational Technology Lab, National and Kapodistrian University of Athens, Greece. mkoulian@phs.uoa.gr

Kourkoutas, Ilias; University of Crete, Greece. larpsy@yahoo.com

Kousathana, Margarita; National and Kapodistrian University of Athens, Greece. mkousathana@yahoo.com

Koutsiouba-Peonidis, Martha; Higher School of Pedagogical and Technological Education, Thessaloniki, Greece. peonidis@edlit.auth.gr

Koutsogiannis, Vassilios; School of Pedagogical and Technological Education, Athens, Greece. macleod@in.gr

Koutsoukos, Anastassios; School of Pedagogical and Technological Education, Athens, Greece. ankoutsoukos@yahoo.gr

Koutsoupias, Nikolaos; Department of Balkan Studies, University of West Macedonia, Greece.

Kumpulainen, Kristiina; Department of Educational Sciences and Teacher Education, University of Oulu, Finland. Kristiina.Kumpulainen@oulu.fi

Kynigos, Chronis; Educational Technology Lab, National and Kapodistrian University of Athens, Greece. kynigos@cti.gr

Kyriakopoulou, Natassa; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. tonia@aueb.gr

Lagos, Dimitrios; School of Pedagogical and Technological Education, Athens, Greece. dlagos@aspete.gr

Lagus, Krista; Neural Networks Research Center, Helsinki University of Technology, Finland.

Lapointe, Judith; University of Texas, USA.

Lefebvre, Sonia; Université du Québec à Trois-Rivières, Canada.

Legault, Frédéric; Université du Québec à Montréal, Canada.

Lehtinen, Erno; University of Turku, Turku, Finland. erno.lehtinen@utu.fi

Levinas, Marcelo Leonardo; Instituto de Astronomía y Física del Espacio and Facultad de Filosofía y Letras, Universidad de Buenos Aires, Argentina.

Ligovanli, Katerina; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. kaligova@phs.uoa.gr

Limon, Margarita; Universidad Autónoma de Madrid, Spain. Margarita.Limon@uam.es

Liu, Shu-Chiu; Physics Education, Institute of Physics, University of Oldenburg, Germany. shu.c.liu@mail.uni-oldenburg.de

Lonka, Kirsti; Department of Learning, Informatics, Management and Ethics, Karolinska Institute, Sweden.

Lundholm, Cecilia; Department of Education, Stockholm University, Sweden. cecilia.lundholm@ped.su.se

Lyndon, Harry; Department of Education and Children's Services, Government of South Australia. Lyndon.Harry@saugov.sa.gov.au

Machamer, Peter; University of Pittsburg, USA. pkmach@pitt.edu

Malandrakis, George; Department of Primary Education, School of Education, University of Crete, Greece.

Mamalougos, Nektarios; Physics Laboratory, Department of Physics, National and Kapodistrian University of Athens, Greece. nektar@phys.uoa.gr

Maragos, George; University of Crete, Greece. gmaragos@phl.uoc.gr

Markopoulou, Anna; School of Pedagogical and Technological Education, Athens, Greece.

Mason, Lucia; Department of Psychology, University of Padua, Padua, Italy. lucia.mason@unipd.it

McCloughin, Taeim; St. Patrick's College, Dublin City University, Ireland. tom.mccloughlin@spd.dcu.ie

McGuigan, Linda; University of Liverpool, UK. l.mcguigan@liverpool.ac.uk

Megalakaki, Olga; Faculté de Philosophie, Sciences humaines et sociales, Université de Picardie, France. megalakaki@wanadoo.fr

Mercier, Julien; Université McGill, Canada.

Merenluoto, Kaarina; Department of Teacher Education, University of Turku, Finland. kaamer@utu.fi

Mol, Athanassios; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. molath@phs.uoa.gr

Morali, Sevgi; Department of Mathematics Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Mosialos, Stergios; School of Pedagogical and Technological Education, Athens, Greece.

Mouzakis, Charalambos; School of Pedagogical and Technological Education, Athens, Greece. hmouzak@primedu.uoa.gr

Nault, Geneviève; Université du Québec à Montréal, Canada.

Nersessian, Nancy; Georgia Institute of Technology, USA. nancyn@cc.gatech.edu

Nevanpää, Tiina; Institute for Educational Research, University of Jyväskylä, Finland. Tiina.Nevanpaa@ktl.jyu.fi

Orfanos, John; School of Pedagogical and Technological Education, Athens, Greece.

Österlind, Karolina; Department of Education, Stockholm University, Sweden. karolina.osterlind@ped.su.se

Pekmez, Esin; Department of Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Peltola, Kari; University of Tampere, Finland.

Petersson, Gunilla; Department of Education, Stockholm University, Sweden. gunillap@ped.su.se

Piliouras, Panagiotis; Pedagogical Department of Primary Education, National and Kapodistrian University of Athens, Greece. ppiliour@primedu.uoa.gr

Pneumatikos, Dimitris; School of Education, University of West Macedonia, Greece. dpnevmat@eled-fl.auth.gr

Portides, Demetris; University of Cyprus, Cyprus.

Potvin, Patrice; Université du Québec à Montréal (UQÀM), Canada. potvin.patrice@uqam.ca

Prinou, Lucia; Department of Primary Education, National and Kapodistrian University of Athens, Greece. lprinou@yahoo.com

Psycharis, Giorgos; Educational Technology Lab, National and Kapodistrian University of Athens, Greece. gpsichar@cti.gr

Psyllos, Dimitrios; Department of Primary Education, Aristotle University of Thessaloniki, Thessaloniki, Greece. psillos@skiathos.physics.auth.gr

Psyllos, Stathis; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. spsillos@phs.uoa.gr

Raftopoulos, Athanassios; Department of Psychology, University of Cyprus, Cyprus. araftop@ucy.ac.cy

Raisis, Vasilis; National and Technical University of Athens. vraisis@central.ntua.gr

Richer, Jeanne; CEGEP de Trois-Rivières, Canada.

Rodriguez Moneo, Maria; Universidad Autσnoma de Madrid, Spain. maria.rodrvguez@uam.es

Rowlands, Mark; University of Exeter, UK. M.N.J.Rowlands@exeter.ac.uk

Russell, Terry; University of Liverpool, UK. qe02@liverpool.ac.uk

Saari, Heikki; University of Joensuu, Finland.

Särelä, Jaakko; Neural Networks Research Center, Helsinki University of Technology, Finland.

Savinainen, Antti; Kuopion Lyseo High School, Finland.

Sfard, Anna; University of Haifa, Israel. annasfard@math.msu.edu

Sheu, Jen Jang; Center of Teacher Education, National Chung Hsing University, Taiwan. sheu2000@ms10.hinet.net

Siereki, Vassiliki; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. vaso@vip.gr

Sintonen, Matti; University of Helsinki, Greece. matti.sintonen@pp.htv.fi

Skopeliti, Irini; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. eskopel@phs.uos.gr

Skordoulis , Constantine; Department of Primary Education, National and Kapodistrian University of Athens, Greece.

Smyrnaiou, Zacharoula; Education Research Center, Ministry of Education, Greece. zacharoula@yahoo.fr

Smyrnaiou, Zacharoula; Education Research Center, Ministry of Education, Greece. zacharoula@yahoo.fr

Souyoul, Alkeos; Department of Mathematics, National and Kapodistrian University of Athens, Greece. alkeos@math.uoa.gr

Stamovlasis, Dimitris; Education Research Center, Ministry of Education, Greece. stadi@cc.uoi.gr

Stathopoulou, Christina; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. chrp@otenet.gr

Stern, Luli; Department of Education in Technology and Science, Technion – IIT, Haifa, Israel. lstern@techunix.technion.ac.il

Strömdahl, Helge; Linköping University, Sweden. helge@kth.se

Svensson, Lennart; Department of Education, University of Lund, Sweden. Lennart.Svensson@pedagog.lu.se

Taskin Can, Bilge; Department of Primary Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Thomas, James; Focus on Learning, Kalamazoo MI, USA.

Tirosh, Dina; Tel Aviv University, Israel. dina@post.tau.ac.il

Trouki, Evie; Educational Technology Lab, National and Kapodistrian University of Athens, Greece. etrouki@cti.gr

Tsagliotis, Nektarios; Department of Primary Education, University of Crete, Greece. ntsag@edc.uoc.gr

Tsaparlis, Georgios; University of Ioannina, Greece. gtseper@cc.uoi.gr

Tselfes, Vassilis; Department of Early Childhood Education, National and Kapodistrian University of Athens, Greece. tselfesv@ecd.uoa.gr

Tsinorema, Stavroula; University of Crete, Greece. tsinorema@phl.uoc.gr

Tsirempolou, Erifylli; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. etsirebol@phs.uoa.gr

Tuominen, Eva; Early Childhood Education Unit, University of Tampere, Finland. Eva.Tuominen@uta.fi

Turnuklu, Elif; Department of Mathematics Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Tzembelicos, Constantinos; School of Pedagogical and Technological Education, Athens, Greece. constantlnetzemb@yahoo.com

Unal, Gul; Department of Primary Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey. gul.unal@deu.edu.tr

Uzuntiryaki, Esen; Middle East Technical University, Ankara, Turkey. esent@metu.edu.tr

Vainas, Kostas; School of Pedagogical and Technological Education, Athens, Greece.

Vamvakoussi, Xenia; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. xenva@phs.uoa.gr

Van Dooren, Wim; National Fund for Scientific Research – Flanders, Centre for Instructional Psychology and Technology, University of Leuven, Belgium. wim.vandooren@ped.kuleuven.ac.be

Vanier, Nathalie; Université du Québec à Montréal, Canada.

Vasama, Satu; University of Oulu, Finland.

Verikios, Petros; Department of Mathematics, National and Kapodistrian University of Athens, Greece. pverikios@math.uoa.gr

Verschaffel, Lieven; Center for Instructional Psychology and Technology, University of Leuven, Belgium.

Viiri, Jouni; Department of Education, University of Joensuu, Finland. jviiri@joyx.joensuu.fi

Vosniadou, Stella; Department of Philosophy and History of Science, National and Kapodistrian University of Athens, Greece. svosniad@cc.uoa.gr

Weil-Barais, Annick; Faculté des Lettres, Langues et Sciences Humaines, Angers, France.

Wihlborg, Monne; Department of Education, University of Lund, Sweden. Monne.Wihlborg@pedagog.lu.se

Winteler, Adi; Faculty of Social Sciences (SOWI), University of the GAF Munich, Germany. s11aaddi@UniBw-Muenchen.de

Wiser, Marianne; Department of Psychology, Clark University, Worcester, MA, USA. mwiser@clarku.edu

Yiannoutsou, Nikoleta; Educational Technology Lab, National and Kapodistrian University of Athens, Greece. yiannou@ppp.uoa.gr

Yildiz, Eylem; Department of Primary Science Education, Buca Faculty of Education, Dokuz Eylum University, Turkey.

Zachariades, Theodossios; Department of Mathematics, National and Kapodistrian University of Athens, Greece. tzaharia@math.uoa.gr

Zemel, Alan; Department of Medical Education, Southern Illinois University, USA.

Zietsman Thomas, Aletta; Institute for Science Education, Department of Physics, Western Michigan University, USA. aletta.zietsman@wmich.edu