



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



9th International Conference on Conceptual Change

August 26-29, 2014
Bologna, Italy

PRE-FINAL PROGRAM

(NOTE: Updated June 30th, 2014)



Conference venue: Santa Cristina della Fondazza, University of Bologna, in Piazzetta Giorgio Morandi.

Conference Co-Chairs

Tamer Amin, *American University of Beirut*
Olivia Levrini, *University of Bologna*

Local Organizing Committee (University of Bologna)

Department of Physics and Astronomy
Barbara Pecori, Olivia Levrini, Eugenio Bertozzi & Giulia Tasquier

Department of Mathematics
Giorgio Bolondi & Laura Branchetti

Department of Education “Giovanni Maria Bertin”
Manuela Gallerani & Ira Vannini

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PROGRAM OUTLINE

DAY ONE – TUESDAY, AUGUST 26TH, 2014

12:00 – 2:30 pm REGISTRATION (COURTYARD)	
2:30 – 3:00 pm OPENING CEREMONY (ROOM A)	
3:00 – 4:30 pm PLENARY LECTURE I (ROOM A) Conceptual Change, Conceptual Metaphor, and Types of Embodiment in Mathematical Thought <i>Rafael Núñez, University of California, San Diego</i>	
4:30 – 5:00 pm COFFEE BREAK (COURTYARD)	
5:00 – 7:00 pm POSTER SESSION (COURTYARD)	5:00 – 6:30 pm PAPER SESSION I (ROOM A) Life and death of conceptual change: Content Analyses and reflections on the paradigm
7:00 pm WELCOME RECEPTION (COURTYARD)	

DAY TWO – WEDNESDAY, AUGUST 27TH, 2014

8:30 – 10:30 am SYMPOSIUM SESSION I		
SYMPOSIUM IA (ROOM B) The interplay between identity and conceptual change: Productive synergies and new directions for research	SYMPOSIUM IB (ROOM C) Modeling and analogy-based research approach for promoting science learning	
10:30 - 11:00 am COFFEE BREAK (COURTYARD)		
11:00 am – 1:00 pm PAPER SESSION II		
PAPER SESSION IIA (ROOM A) Methodological considerations in conceptual change research	PAPER SESSION IIB (ROOM B) Factors influencing conceptual change	PAPER SESSION IIC (ROOM C) Conceptual change in life science: Epistemic and model-based reasoning
1:00 – 2:30 pm LUNCH		
2:30 am – 4:30 pm PAPER SESSION III		
PAPER SESSION IIIA (ROOM A) Learning progressions, developmental changes and curricular issues	PAPER SESSION IIIB (ROOM B) Non-formal reasoning in science: Analogy, metaphor and embodiment	PAPER SESSION IIIC (ROOM C) Mediation and social dynamics in conceptual change
4:30 – 5:00 pm COFFEE BREAK (COURTYARD)		
5:00 – 6:30 pm PLENARY LECTURE II (ROOM A) Promoting Reasoning and Conceptual Change through Argumentation: Challenges and Responses <i>Clark Chinn, Rutgers University</i>		
9:00 pm CONCERT (COURTYARD)		

DAY THREE – THURSDAY, AUGUST 28TH, 2014

8:30 – 10:30 am SYMPOSIUM SESSION II		
SYMPOSIUM IIA (ROOM B) On the nature of continuity or discontinuity between lay and scientific conceptualizations in physics	SYMPOSIUM IIB (ROOM C) The development of quantitative reasoning: Dispositions and biases	
10:30 - 11:00 am COFFEE BREAK (COURTYARD)		
11:00 am – 1:30 pm PAPER SESSION IV		
PAPER SESSION IVA (ROOM A) Conceptual Change in Mathematics Education	PAPER SESSION IVB (ROOM B) Conceptual Change in social domains: Religion, History, Psychology, and Health Work	PAPER SESSION IVC (ROOM C) Conceptual change in science education: Innovations in instruction and assessment
1:30 – 3:00 pm LUNCH		
3:00 am – 4:30 pm PAPER SESSION V		
PAPER SESSION VA (ROOM A) Text Processing and Comprehension for Concept Learning	PAPER SESSION VB (ROOM B) Contrasting and developing models: Knowledge-in-pieces, complexity and conceptual change	PAPER SESSION VC (ROOM C) Teacher Education
4:30 – 5:00 pm COFFEE BREAK (COURTYARD)		
5:00 – 6:30 pm PLENARY LECTURE III (ROOM A) Verbal Language and Conceptual Change in Mathematics Education: Seeking a Comprehensive Framework <i>Paolo Boero, Department of Mathematics and School of Social Sciences, Genoa University</i>		
8:30 pm CONFERENCE DINNER		

DAY FOUR – FRIDAY, AUGUST 29TH, 2014

8:30 – 10:30 am SYMPOSIUM SESSION III	
SYMPOSIUM IIIA (ROOM B) Developing Theoretical Thinking in Mathematics as Conceptual Change: The Role of Argumentation	SYMPOSIUM IIIB (ROOM C) Pre-Service and In-Service Teachers' Professional Knowledge: Diagnosis, Intervention, and Change
10:30 - 11:00 am COFFEE BREAK (COURTYARD)	
11:00 am – 1:00 pm PLENARY PANEL (ROOM A) Topic: Conceptual change in science <i>Michelene (Micki) Chi, Arizona State University, USA</i> Topic: Conceptual change in mathematics <i>Erno Lehtinen, University of Turku, Finland</i> Topic: Conceptual change in the social sciences <i>Cecilia Lundholm, Stockholm University, Sweden</i> Topic: Conceptual change and controversial issues <i>Gale Sinatra, University of Southern California, USA</i> Discussant: Bruce Sherin, Northwestern University	
1:00 – 1:45 pm CLOSING CEREMONY & SIG ADMINISTRATIVE MEETING (ROOM A)	

DETAILED SESSION DESCRIPTIONS

DAY ONE
TUESDAY, AUGUST 26TH, 2014

PLENARY LECTURE I (3:00 – 4:30 PM) (ROOM A)

Chair: Tamer Amin, American University of Beirut

**Conceptual Change, Conceptual Metaphor, and Types of Embodiment in
Mathematical Thought**

Rafael Núñez, University of California, San Diego

According to Embodied Cognition, mathematics, as a conceptual system, is brought forth and consolidated via cognitive mechanisms that ground abstraction in bodily experience, such as conceptual metaphor (among others). But mathematics is a unique body of knowledge. The very entities that constitute what mathematics is are idealized mental abstractions that cannot be perceived directly through the senses. A Euclidean point, for instance, is dimensionless and cannot be actually 'perceived'. Nor can be a transfinite number, or a point at infinity in projective geometry. How then can bodily experience and 'embodiment' possibly play a crucial role in the constitution of mathematical thought? In this talk, I'll address this apparent paradox by discussing various types of 'embodiment' and conceptual metaphors, and I'll show how they play a role in the constitution of mathematical ideas, and in the necessary conceptual change that takes place at different scales, from historico-cultural, to individual. In order to support my arguments, I'll analyze material involving the number-line, continuity in infinitesimal calculus, and issues in axiomatic set theory, drawing from psycho-linguistic experiments and cross-cultural studies, as well as from past and contemporary cases in the history of mathematics.

POSTER SESSION (5:00 – 7:00 PM) (COURTYARD)

Progressive Learning of Physics in High School

Christian Tarchi, Department of Education and Psychology, University of Florence, Italy

Lucia Bigozzi, Department of Education and Psychology, University of Florence, Italy

Paola Falsini, Center of Teachers' Democratic Initiative, Florence, Italy

Carlo Fiorentini, Center of Teachers' Democratic Initiative, Florence, Italy

In this study, a progressive learning approach to physics was compared to a content-centered approach. A main difference related to whether knowledge was transmitted, constructed or co-constructed. Forty six 9th graders studying physics in high school participated in this study over a whole school year. Students' knowledge and mastery of physics concepts were assessed through questionnaires containing both open-ended and multiple-choice questions. Overall, the "progressive learning" group outperformed the content-centered group. Results are discussed in relation to the theoretical background and the experimental teacher's diary of classroom activities. The main conclusion achieved by this study is that the teaching of physics should be slow, cyclic and developmentally appropriate for the context.

A Hermeneutic Approach to Conceptual Change in Mathematics Education

Miglina Asenova, NRD (Nucleo di Ricerca Didattica), Department of Mathematics, University of Bologna, Italy

Giorgio Bolondi, NRD (Nucleo di Ricerca Didattica), Department of Mathematics, University of Bologna, Italy

This paper presents a theoretical framework for a hermeneutic approach to conceptual change in mathematics education, based on the interpretative line proposed by Bagni (2009), and presents an outline of the experimentation implemented to validate this approach. As an investigative tool, Bagni proposes an adaptation of Peirce's semiotic: the initial sign is related to the initial attitude (habit), while the "final logical interpretant" is seen as a mental "effect" (habit change) (Bagni, 2009). The theoretical framework can be used for research on teachers' change of beliefs (D'Amore, Fandiño Pinilla, 2004a; Goldsmith et al., 2014) related to mathematical knowledge, even when this requires a radical reference system reorganization. A meaningful concept on which to perform the research is probability; historically it shows at least a double fracture: a conceptual one, related to the juxtaposition between discrete and continuous approach; and a formal one, linked to its axiomatization. The research can help to understand if behind the superficial layer of insecurity due to initial training, the rejection many teachers have against probability may be due to the characteristics of deep interpretation of the involved concepts. A reflection on its historical evolution could be an efficient intervention to produce a change in teachers' beliefs.

Towards a History of the Origins of the Theory of Embodied Mathematics: The Contribution of Ernst Mach

Verena Zudini, Department of Mathematics and Earth Science, University of Trieste, Italy

Luciana Zuccheri, Department of Mathematics and Earth Science, University of Trieste, Italy

We describe our research carried out in the history of mathematics education based on integrated fields - i.e. that of the history of science (especially cognitive science) and that of mathematics education with the aim of contributing to the study of the origins of embodied mathematics. The importance of the muscular activity in the process of creating and developing concepts resounds in the modern theory of embodied cognition applied to mathematics teaching, as described in the works of Rafael Núñez and George Lakoff. Our study focuses on the contribution given in this direction by Ernst Mach (1838-1916), the famous Austrian physicist, physiologist, and philosopher. As an example of the application of these ideas of Mach to mathematics education, we have found a text from 1913 dealing with the training of mathematics teachers in the Austrian "Gymnasium", whose preface was written by Mach himself. We have analyzed it from a historical and epistemological point of view, presenting its theoretical framework and giving some examples of application, in particular to infinitesimal calculus.

Metaphors and Motions in Integer Arithmetic: Changes in Student Conceptions Due to Walking Paths or Collecting Chips

Julie Nurnberger-Haag, Department of Counseling, Educational Psychology & Special Education, Michigan State University, USA.

Understanding integers is a critical competence in mathematics. Students, however, encounter cognitive obstacles similar to mathematicians in history. Although pedagogical recommendations to address these obstacles have been contradictory, multiple models are often used in U.S. schools. I posited that the cognitive obstacles and contradictory results are due, in part, to students' physical motions and the conceptual metaphors activated when using pedagogical models. This study quantitatively and qualitatively compared the effects of two instructional models for integer operations that draw on different conceptual metaphors (a chip model or a number line model) on students' knowledge and reasoning patterns. I taught the equivalent of about eight 50-minute lessons to about 165 students the year before they would normally learn integer operations using a pre-post design with random assignment of 8 intact classes to each model. I expected affordances and constraints of each model—different physical motions (consistent or inconsistent with certain mathematical ideas) and conceptual metaphors (collecting objects, moving on a path, or measuring stick) to affect how students reasoned about and calculated with integers. Some preliminary results will be shared with the goal of better understanding why each model may support or hinder specific aspects of integer learning.

Noticing Verbally and Physically Expressed Conceptual Metaphors for Mathematics: A Method for Conceptual Metaphor Analysis

Julie Nurnberger-Haag, Department of Counseling, Educational Psychology & Special Education, Michigan State University, USA

Language-based knowledge is often privileged over non-verbal understanding. This is problematic, particularly, as new evidence emerges that those with stronger mathematics understanding often have stronger spatial skills and that students often know more than they can express in words. This should be problematic both from the perspective of how we provide students the opportunity to learn mathematics as well as the ways we assess that knowledge. In this poster, I share an emerging research method for analyzing expressions of conceptual metaphor-based understanding that students communicate during video recorded mathematics interviews as well as written tasks on which students were asked to draw and explain in words. While some other work in mathematics education has focused on the use of gesture, the method reported here seeks to identify conceptual metaphors expressed in any form (whole body motions through space, head movements, gestures, etc.). I will share the method and conceptual-metaphor-specific coding tool I developed for the topic of negative numbers that could be used to study any topic that uses the same underlying conceptual metaphors (object collection, measuring stick, or motion along a path).

“Conceptual Change” as a Guiding Principle for the Professional Development of Teaching Staff

Claudia Walter, Zentrum für Hochschuldidaktik – DiZ

Christian Kautz, Hamburg University of Technology (TUHH)

Franz Waldherr, Zentrum für Hochschuldidaktik – DiZ

Peter Riegler, Ostfalia University of Applied Sciences

This presentation describes an attempt to use a conceptual change approach for the professional development of tertiary-level teaching staff. While novice instructors often have an instructor-centered view of teaching and, consequently, use traditional teaching formats, professional development programs (PDPs) are most often based on a constructivist framework that favors student-centered learning scenarios. Prior research suggests that the development of instructors' beliefs about teaching can be interpreted in terms of conceptual change, and that PDPs should take this perspective into account. Our study documents instructors' changes in the perception of their own teaching in the context of a professional development program based on conceptual change. A questionnaire was used to measure initial conceptions about teaching before participation in a PDP. The identical questionnaire was administered a second time after the seminar and again three months later. The data obtained suggest that instructors' conceptions may at first deteriorate (when regarded from a constructivist perspective) and then improve again with further practice. This result has challenged us to propose a further investigation of the conceptual change among STEM instructors, its manifestation in teaching practice, and the possibility to affect both through PDPs.

Resonantly Guided Conceptual Change along the Construction of “Number Sense” in First Grade

Paolo Guidoni, Dipartimento di Scienze Fisiche, Università Federico II, Napoli, Italy

Maria Mellone, Dipartimento di Matematica e Applicazioni, Università Federico II, Napoli, Italy

Ciro Minichini, Dipartimento di Scienze Fisiche, Università Federico II, Napoli, Italy

We evoke here a revealing passage along the construction of the ‘sense’ of number and operations as it was successfully guided in a first class of primary school (6-7 yrs). Teaching strategies were a blend of three main ingredients, reciprocally harmonized on the basis of long-term previous experimentation and of comprehensive cognitive modeling: (i) emotional, bodily, cognitively purposeful involvement of children - from telling to action to elaboration to representation - into an ongoing narrative, whose structures and outcomes were progressively co-determined by interlaced numerical constraints (always in terms of very small numbers);(ii) flexible and varying representational strategies: from group actions, to verbal expressions; from (re)arrangements of ‘objectual’ numeric symbolizations accounting for both the crucial categories of objects and events, to graphics; and (iii) systematic classroom discussions after individual or small group work, ending by ‘forward drivings’ along a sheaf of accepted and shared ways-to-look-at. The main indicator for favourable and/or problematic evolution along the planned pathway was then the ability of children to appropriate the sense of numerical patterns, becoming creatively engaged into variational and coherent wordings, actions, representations, suggestions, metacognitive comments, etc. Pictures of different, evolutive, objectual’ representations will be shown as an example.

A Case Study of Conceptual Change – Beyond Constructivism

Yaron Schur and David Yellin Academic College, Jerusalem, Israel

A case study examined the conceptual change processes of a middle school student through the use of the Thinking Journey method (Schur & Galili, 2009). The student, Tami, learnt for a whole year about the Earth, and put it in the sky. Her first drawing describes the Earth and the moon near the clouds in the sky, while she stands on the ground. The mediation did not deal with the Earth's concept but with the connection to the place where the student lived (Israel) and the Earth. Then the student was able to compare the moon to the earth, and by understanding that one can stand on the moon, she could draw herself standing inside the sphere of the Earth. This shows a conceptual change to Nussbaum's notion 2 (Nussbaum, 1985). Tami had emotional constraints and did not feel able to connect herself to the Earth. The thinking journey enabled Tami to go out of her egocentric point of view and feel free to connect herself to the Earth. She used her imagination, freeing herself from the constraints of the reality around her and only then was she able to connect herself to the learnt concept.

The Conceptual Change Referred to the Way of Thinking Genders-Education in Preschool Educators

Manuela Gallerani, University of Bologna, Italy

This paper presents a qualitative research study on the conceptual changes involved in rethinking gender education in pre-school educators (pre-school and kindergarten children from 0 to 6 years) that occurred as a result of participation in a training course. The educators, after having finished the training course (which involved proper training; focus group; role-playing; cooperative learning), changed their point of view towards and their representations of gender: their language became more and more precise (in a scientific way). The educators developed an effective cognitive accommodation and then were able to prepare carefully new and more effective conceptual models on gender to build and share with the children at the preschool age. The research was conducted with pre-school educators and teachers, because it is at the preschool age that the socialization to the roles of boys and girls develops, when the first sexist stereotypes are formed and when they will (or will not) develop appropriate language about gender. Moreover, the research was conducted on educators and teachers because – as caregivers along with parents - they set a daily example and gender education may be the promoter of conceptual change that it is realized and consolidated in the daily "learning by doing", starting from the early years of children's life.

Learning Science and Mathematics Requires Inhibition of Prior Knowledge

Stella Vosniadou, National and Kapodistrian University of Athens

Kalliopi Ikospentaki, National and Kapodistrian University of Athens

Despina Lepenioti, National and Kapodistrian University of Athens

Anna Chountala, National and Kapodistrian University of Athens

Many science and math concepts taught to children are counter-intuitive and require the inhibition of empirically supported everyday intuitive knowledge. We hypothesised that the considerable conceptual changes in science and math domains that occur during childhood as a result of development and learning implicate executive functions (EFs), and particularly the executive functions of inhibition and shifting. In this study, we examined this hypothesis by

looking at relationships between children's performance in two conceptual change tasks and two Stroop-like inhibition and shifting executive function tasks. Sixty-nine children, 10 to 12 year-olds, participated in the study. The results showed high correlations between performance in the conceptual change tasks and the executive function tasks, indicating that executive function abilities are implicated in conceptual change processes.

Supporting Fraction Understanding with External Representations

Despina Lepenioti, National and Kapodistrian University of Athens

Stella Vosniadou, National and Kapodistrian University of Athens

A training experiment using Cognitive Tutor Authoring Tools was designed to compare the effects of two types of external representations, (pies and number lines), on the development of students' understanding of the concept of fraction, and the interpretation of fraction as part of a whole or/and as a measure. The training sessions were based on the series of explanatory frameworks found in Stafylidou and Vosniadou (2004). Eighty-six 6th grade students participated in three training sessions that required them to pair or create external and symbolic representations of fractions. A pretest-posttest experimental design was used, with two experimental groups and a control. Results showed that only the number line group performed significantly better on the posttest over the control group. An analysis of the differences between the two experimental groups in the specific tasks used showed that the two external representations encouraged different interpretations of fractions. The number line encouraged the understanding of fraction equivalence and the interpretation of fractions both as a measure, whereas the pie external representation encourages only the interpretation of fractions as part-whole.

Analyzing Conceptual Change of Current, Voltage and Resistance in High-School Students Through The Use of Blended-Learning Strategies

Daniel Sánchez-Guzmán, Unidad Legaria del Instituto Politécnico Nacional, Mexico City

Diana López-Tavares, Unidad Legaria del Instituto Politécnico Nacional, Mexico City

Ricardo García-Salcedo, Unidad Legaria del Instituto Politécnico Nacional, Mexico City

Physics education is one of the most recent areas in science education in development. Many strategies have been presented and tested in different contexts. One of these areas is related to the use of Information and Communication Technologies (ICT) added to the instructional design. Some ICT tools used for enhancing learning are simulations of physical phenomena for the comprehension of a physical concept that physically cannot be seen; and the use of intelligent tutoring systems (ITS) for training in the use and manipulation of formal mathematical models of physical phenomena. Present work will show the results obtained from an *in vivo* experiment with high-school students where the use of simulations and ITS were added as additional resources for promoting a conceptual change in the concepts of current, voltage and resistance, in the context of the topic of electric circuits. We present a normalized gain based on the application of a pre-test and post-test and complemented information with the application of the concentration factor of both tests obtained from the implementation of an instructional design. The instructional design was implemented during one week and some of the activities had to be done as homework. The results show a better comprehension of the concepts learned and a medium-high normalized gain. At the end of the instruction a semantic differential will be applied to the thoughts and impressions of the students doing these activities.

Learning Natural Selection from Correcting Common Misconceptions

Christa Asterhan, Hebrew University of Jerusalem

Miriam Babichenko, Hebrew University of Jerusalem

Karin Hafuta, Hebrew University of Jerusalem

Previous research has shown benefits of studying and correcting erroneous examples, predominantly in elementary school mathematics. The present study tests the effect of error correction activities on student understanding of natural selection. 62 undergraduates learned about natural selection, completed a test assessing their conceptual understanding. They then either corrected 4 erroneous explanations based on common misconceptions (error correction condition), or answered the same four items themselves (control condition). Moreover, half of the students in the error correction condition were led to believe that their corrections would be sent to the error-making students, whereas the other half were not. Conceptual understanding was assessed a week following. Results of pre-post test gains showed an overall effect of error correction over the control condition. Gains of students that believed in a socially relevant action (sending their corrections to the relevant parties) were not found to be statistically significant higher than those of students in the other error correction condition. Directions for future research will be outlined in the presentation.

Exploring Context-Based Tasks: How Does Complexity and Transparency Influence Students' Deep Initial Learning?

Marcela Pozas, University of Koblen-Landau

Patrick Löffler, University of Koblen-Landau

Wolfgang Schnotz, University of Koblen-Landau

Alexander Kauertz, University of Koblen-Landau

In science education, students need to solve problems from their everyday life context by applying physics concepts and principles. These problems have surface features and deep structures which can influence students' problem representation, deep initial learning, and the ease of solving a problem (Chi & VanLehn, 2012). Despite thorough research on how novices and experts categorize physics problems based on surface or structural features and how it affects deep initial learning, there is still little discussion on an instructional approach that can enhance students' deep initial learning in order to extract a problem's deep structure. Following the results from Löffler & Kauertz (in press), the aim of our study was to examine how complexity and transparency of context-based problems can improve students' deep initial learning by extracting the relevant surface features that can be linked to deeper cues used to represent and solve the problem. A sample of 219 tenth grade students from German High Track schools received each a different problem-solving task which varied in level of contextualization, complexity, and transparency. The research project is currently in its early stages of development; results and implications for further research will be discussed.

Conceptual Change within the framework of Cultural Content Knowledge (CCK)

Igal Galili, The Amos de-Shalit Science Teaching Center, The Hebrew University of Jerusalem

Physics is comprised of a few fundamental theories, which can be structured as cultural content knowledge (CCK). The triadic structure codifying such a conception of fundamental theory in physics (nucleus-body-periphery) allows the depicting of conceptual change both in science and

in the knowledge of individuals as a breakthrough between the periphery and nucleus in a certain theory (of physics) or knowledge system (of an individual). I will exemplify such a visualization of conceptual change in science and students. The structural similarity of conceptual change from the perspective of ontogeny and phylogeny revives the idea of recapitulation suggested in psychology at the beginning of the twentieth century and has been rejected since then for the role of social environment in education. However, a certain similarity remains and some of its implications to education seem reasonable and correct. I will exemplify them and depict the implications to physics curriculum, the changes required by such understanding.

PAPER SESSION I (5:00 – 6:30 PM) (ROOM A)

**LIFE AND DEATH OF CONCEPTUAL CHANGE:
CONTENT ANALYSES AND REFLECTIONS ON THE PARADIGM**

Chair: Gale Sinatra, University of Southern California

Content Analysis of Theories and Teaching Strategies on Conceptual Change Research in Science Education from 1982 to 2012

Mei-Hung Chiu, National Taiwan Normal University

Jing-Wen Lin, National Don-Hwa University

Chin-Cheng Chou, National Taipei University of Education

This content analysis study reviewed the current research on conceptual change in science education. The review included research located in the DoRise system (Database of Research in Science Education) in Taiwan and articles published in five selected international science education journals between 1982 and 2012. Three hundred and eighty-three articles in the international journals (including 26 English papers from researchers in Taiwan) and 60 Chinese articles from Taiwan were analyzed. There were five major findings. First, about two thirds of the studies from outside of Taiwan used the epistemological and instructional perspectives, respectively. Nearly two thirds of the Taiwanese articles investigated the instructional perspective and only 28% followed the epistemological perspective. Second, we found that 62.7% of the international publications were related to conceptual change teaching strategies while 67.4% for the articles by Taiwanese researchers. Third, physics was the main discipline examined both in the international and national studies. Fourth, qualitative data analysis was ranked first among all the methods we investigated while Taiwan appeared to integrate mixed methods. Fifth, Taiwan ranked third out of 32 countries in terms of the number of publications from 1982-2012 but was the first non-English-speaking country. Recommendations for researchers and educators are provided.

A Content Analysis of Research on Methodological Issues of Conceptual Change Published in Selected Science Education Journals From 1982-2011

Huey-Lien Kao¹, Mei-Hung Chiu^{2}, Chorng-Jee Guo³, Jing-Wen Lin⁴, Miao-Hsuan Yen⁷, Yu-Ling Lu⁶, Jun-Yi Chen⁵, Jiachi Liang⁸, Hsiao-Ping Yu⁹, Fu-Yuan Chiu¹⁰, Chun-Keng Liu¹¹, Wanchu Huang¹²*

¹*National Pingtung University of Education*

- ²*National Taiwan Normal University*
³*National Changhua University of Education*
⁴*National Dong-Hwa University*
⁵*National Taipei University of Education*
⁶*National Chiayi University*
⁷*Yuan Ze University*
⁸*National Taichung University of Education*
⁹*National Hsinchu University of Education*
¹⁰*Taipei Chenggong High School*
¹¹*University of Taipei*

The purpose of this study was to reveal what kind of research has been carried out and what research methods were applied for promoting science learning from the selected journal articles during the period of 1982 through 2011 in the area of conceptual change. We adopted a content analysis on 149 selected articles that were limited to social sciences citation index journals and free full text directly from ERIC. The inter-rater reliability was calculated to be 83.03%. The results showed that empirical studies were always the main approach. Second, the majority of studies focused on comprehension and achievement in science learning whereas few studies investigated the affective and practical skills components of conceptual change. Third, as for the data collection, articles using quantitative methods increased after the period of 1997-2001. Fourth, as for instruction, “conceptual conflict,” “multimedia,” “cooperative learning,” “reputational/conceptual change text,” “experimentation,” and “models and modeling (including analogy)” were found to be receiving increasing attention over the years. Finally, nearly half of the studies (47.1%) were applied for a short-term (less than one month). This study suggests that we need to continue putting more effort into conceptual change research in order to improve our understanding of science learning.

Anticipating the Death of Conceptual Change: Reflections on the Paradigm

Andrea A. diSessa, University of California, Berkeley

Recent studies in which I have participated have pressed me hard to think about basic assumptions underlying the study of conceptual change. This talk lists a number of outstanding issues that might question the way we construe conceptual change. At core, many researchers think about conceptual change as essentially revolutionary. However, where is the data that actually demonstrate the revolution? When I have undertaken microgenetic study of conceptual change, I have not located revolutions, but only surprising continuity. How might we have been misled, and how might we really find out whether revolutions are necessary? I elaborate on ways in which learning might take a lot of time, and yet still not involve revolutions. I discuss how the pressure of coherence in learning might not require revolutions, even if, for some, it is precisely coherence that demands revolutionary change. I observe that even if there are revolutions in some “learning sequences,” there may be other such sequences, say mediated by a radically shifted representational infrastructure, that do away with them. Finally, I advocate thorough, fine-grained study of extended learning as a way of finding out whether “conceptual change” is necessarily revolutionary, or not.

DAY TWO
WEDNESDAY, AUGUST 27TH, 2014

SYMPOSIUM SESSION I (8:30 – 10:30 AM)

SYMPOSIUM IA (ROOM B)

**THE INTERPLAY BETWEEN IDENTITY AND CONCEPTUAL CHANGE: PRODUCTIVE
SYNERGIES AND NEW DIRECTIONS FOR RESEARCH**

Organizer: Laura Branchetti, University of Palermo

Discussants: Andrea A. diSessa, University of California, Berkeley

Paolo Guidoni, Dipartimento di Scienze Fisiche, Università Federico II, Napoli

Chair: Sibylle Reinfried, University of Teacher Education Central Switzerland Lucerne

The role of identity in the learning process, in its different delineations, is becoming a challenge for contemporary society. Research on conceptual change has contributed significantly to the theoretical exploration and the construction of models of learning, especially in science education. However, the interplay between these two fields is currently little investigated in STEM education. The symposium intends to explore the possible interplay between research on identity and conceptual change and, moreover, to formulate some common research questions, and look for new research strands. The conjecture is that, on the one hand, identity as self-narrative affects the processes of conceptual change as well as their interpretation, and, on the other hand, instruction inspired by models of conceptual change affects the construction of students' identity. But how? Within the debate on identity, all the speakers stand in favor of a view of identities as stories (as opposed to considering that identities are expressed through stories), which are constantly created and re-created in dialogical interactions between people. This common ground will allow the three contributions to highlight the different angles from which they address the issues of learning and conceptual change: the commognition perspective (first contribution), the situated cognition perspective (second contribution) and the cognitive perspective of the Knowledge-in-Pieces (third contribution). This symposium will be arranged so that each speaker can (i) illustrate her/his specific position with respect both to the issue of identity and to the research on learning and conceptual change, (ii) provide an example of how identity interacts with learning of a discipline and/or vice versa, and (iii) indicate prospects and challenges for new research in this direction.

Contributed papers:

How identity supports or obstructs meta-level learning

Anna Sfard, University of Haifa, Israel

Identity as patterns of participation

Melissa Gresalfi, Vanderbilt University, USA

Disciplinary learning as a vehicle for identity construction

Olivia Levrini, University of Bologna, Italy

Paola Fantini, Liceo Scientifico “A. Einstein”, Rimini and University of Bologna, Italy

Giulia Tasquier, University of Palermo, Italy

Mariana Levin, Michigan State University, USA

SYMPOSIUM IB (ROOM C)

MODELING AND ANALOGY-BASED RESEARCH APPROACH FOR PROMOTING SCIENCE LEARNING

Organizers: Mei-Hung Chiu, National Taiwan Normal University

Jing-Wen Lin, National Dong-Hwa University

Discussant: Kurt VanLehn, Arizona State University

Chair: Noemi Waight, University at Buffalo, SUNY

The purpose of this symposium is to show how modeling-based, analogy, and conceptual conflict approaches promote students' learning in science. Each presentation takes a unique perspective in discussing the role of multiple representations (MR), analogy, and conceptual conflict scenarios in the modeling process. The first study by Chiu, Chung, Lin, and Yang adopted three phases and eight stages of modeling processes for teaching the concepts of redox and electrochemistry to 12th graders in Taiwan. The results showed there was a significant difference on the posttest between the two groups (dynamic vs. static MR) when taking the pretest as a covariate. The second study by Chung and Chiu investigated three groups of 12th grade students' learning of crystals and intermolecular attraction. The results of post hoc tests (LSD) revealed that modeling with multi-MR (MM) group outperformed the modeling group (M) and both MM and M groups outperformed the control group. The third study by Lin, Tu, and Lin developed an analogy-based modeling ability questionnaire to investigate 6th graders' modeling ability as well as the relationship between modeling ability and students' understanding of the concept of electric circuits. They found that the questionnaire with good reliability and “model validation” and “model construction” were more highly correlated with students' performance related to the electric circuit than the relationship between student performance and “model deployment.” The fourth article by Lin and Lin investigated the effectiveness of self-generated analogy in the learning of batteries. The results showed that younger students benefited from the use of analogy but only if the analogy fell into the same type of category as the electric circuit. Finally, the fifth study by Chiu, Chou, Liaw, & Wu investigated how students responded to conceptual conflict scenarios with an innovative technology, facial recognition technology. They found that that the lack of FMES change was shown to indicate a low likelihood of conceptual change. It also revealed that there is a significant relationship between FMES changes and students' macro-submicroscopic understandings. In sum, the modeling approaches presented here open new avenues for better understanding scientific concepts and for building modeling competence in science practice.

Contributed papers:

Modeling-Based Approach for Teaching and Learning of Redox and Electrochemistry Via the Use of Multiple Representations and Explicit Explanations

Mei-Hung Chiu, National Taiwan Normal University

Shiao-Lan Chung, National Taiwan Normal University & New Taipei Municipal New Taipei Senior High School, Taiwan

Yen-Cheng Lin, National Taiwan Normal University
Ya-Ting Yang, National Taiwan Normal University

Effects of a Modeling Approach on Twelfth Grade Students' Learning of Crystals and Intermolecular Attraction

Hsiao-Lan Chung, New Taipei Municipal New Taipei Senior High School, Taiwan & National Taiwan Normal University
Mei-Hung Chiu, National Taiwan Normal University

Development and Application of the Analogy-Based Modeling Ability Questionnaire – An Example of Electric Circuits

Jing-Wen Lin, Graduate Institute of Science Education, National Dong-Hwa University
Li-Ping Tu, Graduate Institute of Science Education, National Dong-Hwa University
Pi-Hui Lin, Graduate Institute of Science Education, National Dong-Hwa University

Could Self-Generated Analogies Foster Sixth Grade Students' Model Reconstruction in Electric Circuits?

Pi-Hui Lin, National Dong-Hwa University
Jing-Wen Lin, National Dong-Hwa University

Exploring the Student Responses to conceptual conflict phenomenon via the Use of Facial Recognition Technology

Mei-Hung Chiu, National Taiwan Normal University
Chin-Cheng Chou, National Taipei University of Education
Hongming Liaw, National Taiwan Normal University
Wen-Lung Wu, National Academy for Educational Research

PAPER SESSIONS II (11:00 AM – 1:00 PM)

PAPER SESSION IIA (ROOM A)

METHODOLOGICAL CONSIDERATIONS IN CONCEPTUAL CHANGE RESEARCH

Chair: Ricardo Karam, University of Hamburg

Applications of Learning Analytics to the Study of Conceptual Change

Bruce Sherin, Northwestern University

Educational researchers have recently become interested in new types of computational methods. These new methods—which have been variously called learning analytics and data mining—make it possible for us to perform automated analysis on a variety of types of data. In many applications, these computational methods are applied to data that take the form of computer-generated log files. However, techniques from statistical natural language processing (SNLP) can be used to discover patterns in many types of textual data, regardless of how that data was gathered. In prior work, I reported on research in which I applied techniques from SNLP to transcripts of interview data. In those interviews, middle school students were asked,

in a relatively open manner, to explain the Earth's seasons. The new work reported here extends that prior work in two ways. First, I apply the same automated analysis techniques to new interviews and subject matter, namely, a corpus of 54 interviews in which middle school students were asked questions pertaining to energy use in the human body. Second, I reflect systematically on the prospects of these new computational methods for research on conceptual change.

Understanding and Mind Wandering: An Account of the Silent Conceptual Experiences of the Students

Gilles Dieumegard, LIRDEF (Interdisciplinary Laboratory of Research on Didactics, Education and Training), Faculty of Education of University Montpellier 2, France.

Nicolas Perrin, CRAFT (Design and Research on Activity for Work & Training), University of Geneva Haute Ecole Pédagogique /Vaud, Lausanne, Switzerland.

Fine-grained methods studying knowledge in transition proceed habitually by interaction analysis in small groups of students. But how could we investigate processes underlying conceptual change in large-group situations in which most students just attend and may encounter mind wandering or attention lapses? We focused on large group but rather participative situations: we studied collective debriefings of role-playing activities in teacher education. We used the “course of action” method from ergonomics in which a “self-confrontation” interview technique aimed at accessing not only the manifest experiences of students who were participating in interaction but also to the silent experiences of those just attending these interactions. Data were analyzed by indentifying units of experience and then distinguishing these experiences conceptually and relating them. Afterwards we assessed the alignment of the conceptual experiences of each student with those of the teacher. Results showed that the participation of the students in the debriefings may not reflect their alignment on the conceptual elements the teacher intended to present. Therefore, the teachers have to avoid a “participative illusion” regarding the conceptual understanding in such large-group situations.

Content Analysis for Recognizing Threads in Conceptual Change Research

Laura Branchetti, University of Palermo, Italy

Giulia Tasquier, University of Palermo, Italy

Alberto Bernardini, Politecnico di Milano, Italy

Since its origins - the publication of the milestone paper of Posner, Strike, Hewson and Gertzog in 1982 - conceptual change has been one of the main research issues in science education. The literature on conceptual change is wide and some researchers have already tried to identify the main threads in this research strand. In some review papers the main articles have been classified according to different criteria, like “fragmentation and coherence”. Our work stems from these overview papers and aims at contributing to the literature review on conceptual change research. In particular, we will present and discuss a new method for identifying research threads or currents of thought. The analysis of the collection uses both a quantitative linguistic software and an algorithm inspired by the classical information retrieval procedure LSI (Latent Semantic Indexing). The selection of the terms to build the reference dictionary needed for the algorithm is semi-automatic. In the paper, we discuss the extent to which such software and algorithm are useful for (i) aggregating and classifying similar papers in terms of topics; and (ii) checking the coherence between the results of the automatic classification

procedure and the effective differences among the papers, in order to visualize more deeply the trends in conceptual change research.

PAPER SESSION IIB (ROOM B)

FACTORS INFLUENCING CONCEPTUAL CHANGE

Chair: Henrik Saalbach, Saarland University

Factors Facilitating Conceptual Understanding in Experimentation

Chrisotpher Osterhaus, University of Education Freiburg

Susanne Koerber, University of Education Freiburg

Conceptual understanding of experimentation is an important aspect of scientific thinking. Studies in elementary school have shown basic abilities, but also large interindividual differences and inconsistent results depending on the form and context of the task. The present study aimed to inspect three factors that might have facilitating effects on understanding experimentation: the direction of the causal effect (generative vs. inhibitory), the (in-) congruency with children's belief system, and the focus of the experiment (helping vs. finding out). Altogether, 135 fourth-graders answered 14 closed-response items that assessed their understanding of experimental designs. Seven of these items were varied across two conditions with respect to these three factors. Results revealed that the three manipulations had a significant (facilitating) effect on children's performance. This, however, was only the case for children who were identified in a latent class analysis as "bloomers" (children with a beginning, but not yet full understanding of experimentation). Performance on the remaining items, which were the same across conditions, did not differ. Our results show that a consideration of these facilitating factors is important in both research (under- vs. overestimating children) and practice (scaffolding), and that facilitating understanding requires educators to take into account students' current level of ability.

Learning For Understanding and Emotional Processes

Yaron Schur, David Yellin Academic College, Jerusalem, Israel

Efrat Nevo, Michlalah Jerusalem College, Jerusalem, Israel

The difficulties of experiencing conceptual change (Carey, 2009) lead us to examine the emotional processes of students during a conceptual understanding experience. 28 educators learning in academic courses (2009 – 2011) experienced a mediated interaction that asked them to place themselves on the moon and draw the day and night on the Earth from there. The students were asked to fill a questionnaire and describe the emotional processes they have gone through. 89% expressed emotions. 61% of the students expressed mixed feeling, positive and negative. Feeling lack of knowledge and not being accustomed to this kind of task were the main causes for expressing feelings. In this context, they expressed negative feelings such as fear and frustration, and positive feelings such as curiosity and challenge. 18% were afraid that their colleagues would be aware of their scientific ignorance. They showed in their drawings and explanations multiple ways to disguise their lack of knowledge. Our research shows, that the fact that the students were emotionally involved, enabled them to be open for change. The mediation was important for containing the feelings of the students, leading them to carry on with their work on the task.

Using Depictive Images for Addressing the “Liminality” of Threshold Concepts: A Method to Support Conceptual Change

Natasa Lackovic, University of Nottingham, UK

An important characteristic of threshold concepts is “liminality” (Meyer and Land, 2006): a transitional space in which students grapple with concepts in order to move to more advanced levels of concept understanding. To support such movement, a method, “IBCI” (Image-Based Concept Inquiry), was designed to engage postgraduate Education students in selecting or creating digital images to represent tutor-chosen threshold concepts. Students wrote personal explanatory narratives and critiques linking image and concept. This was followed by peer discussion, and consolidated with a tutor-led plenary. The project was developed and implemented as design-based research (DBR) and action research (AR) and extended over two academic years.

PAPER SESSION IIC (ROOM C)

CONCEPTUAL CHANGE IN LIFE SCIENCE: EPISTEMIC REASONING AND MODEL-BASED REASONING

Chair: Kai Niebert, Leuphana University Lueneburg

Belief-Forming Scientific Practices in a Pre-School Science Project about Snails: The Meaning of Evidence

María Pilar Jiménez-Aleixandre, Universidade de Santiago de Compostela, Spain
Sabela Fernández-Monteira, Universidade de Santiago de Compostela, Spain

There is a growing interest in students’ engagement in epistemic practices (Chin et al., 2011), complementing studies about epistemic beliefs. Most papers in this area focus on secondary school, however, a handful of studies (Metz, 2008; 2011; Mantzicopoulos et al., 2009) show that sustained participation in scientific inquiry supports young children development of epistemic reasoning. This paper examines pre-school children (3 and 5 year old) engagement in generating and evaluating evidence during a year-long inquiry project about snails, and the associated meanings that they construct for “doing science”. The research question examines how the meanings for what constitute evidence, and appropriate criteria for evaluating it are constructed and refined during the project, and the differences between age groups. The context is a research-practice partnership with pre-school teachers. The participants are three classes of pre-school children (N=72). They were engaged in a project about snails, involving pursuing their own questions, planning and carrying out investigations, collecting data and drawing conclusions, under the guidance of the teachers. The results show that children developed meanings of increasing sophistication about evidence. The differences between age groups are not substantial, which would support Metz’s (2011) contention about the relevance of instructional opportunities over developmental constraints.

How Does Children’s Learning About Plants’ Functions Shape Their Emerging Concept of Plants?

Gertraud Benke, University of Klagenfurt, Austria

Andrea Holzinger, University College for Teacher Education in Carinthia

This paper presents our findings about elementary school children's functional thinking about plants. Before and after an extended learning sequence (circa 12 units, all videotaped) about plants and functional uses of plants, e.g. for making cloths, six children (3rd and 4th grade) were interviewed on their present understanding on plants, differentiating them from animals and inanimate objects (partly based on the protocols by Hatano and Inagaki, 2002), and their understanding of plant properties and their relation to possible uses of plants. Additionally, children drew an "ideal plant" in small groups as part of their class-work at the beginning and end of the unit, and made a case for "their plant" to their peers. We conjectured that functional aspects would be more prominent in children's reasoning about plants after the unit, and that teleological arguments would occur more frequently. In a sorting task, it was also expected that functional properties became an option for grouping plants. Overall, the study will contribute to our understanding of the degree of volatility of children's emerging conceptual structure of natural kinds in response to a specific instructional content stressing functional and thereby possibly perceived teleological aspects.

Conceptual Change through Model-Based Inquiry in Genetics for Middle School Science Students

Ronald Rinehart, Rutgers University

Clark A. Chinn, Rutgers University

Ravit Golan-Duncan Rutgers University

Moraima Castro-Faix, Rutgers University

Unraveling the causal dimensions of biological inheritance is a significant cognitive achievement for science students. Students often struggle to develop robust understandings of foundational concepts in genetics because many of the entities involved are invisible and unfamiliar (e.g. genes, alleles, chromosomes) and processes span multiple time and space scales (Bahar et al., 1999; Horwitz, 1996; Tsui & Treagust, 2003). We present the results of a three-day modeling activity in which 7th grade life science students developed their own models of inheritance in response to multiple evidence sets. We found that students were capable of developing rules that: (a) were consistent with the evidence provided, (b) were internally consistent, (c) increased in the degree to which they captured causal mechanism, and (d) increased in their consistency with normative explanations of inheritance. This modeling activity facilitated the development of more sophisticated student thinking about genes, traits, and patterns of inheritance. This finding contrasts with other research that suggests that guided-constructivist inquiry methods, like those used here, are ineffectual (Kirschner et al., 2006). Moreover, it shows that opportunities to invent solutions can generate productive success in addition to productive failure (Kapur & Bielaczyc, 2012).

PAPER SESSION III (2:30 – 4:30 PM)

PAPER SESSION IIIA (ROOM A)

LEARNING PROGRESSIONS, DEVELOPMENTAL CHANGES AND CURRICULAR ISSUES

Chair: Ronald Rinehart, Rutgers University

Development and Validation of a Learning Progression of Basic Astronomy Phenomena

Italo Testa, University Federico II, Department of Physics, Naples, Italy

Silvio Leccia, INAF, Astronomical Observatory of Capodimonte, Naples, Italy

Emanuella Puddu, INAF, Astronomical Observatory of Capodimonte, Naples, Italy

Learning progressions have been proposed to describe and interpret students' understanding of core concepts in science. There is an increasing consensus in the science education community on the pivoting role of validated learning progressions, since they can be useful means to improve teaching practices at different school levels. In this paper, we report about the development and validation of a learning progression about three basic astronomical phenomena: change of seasons, solar and lunar eclipses and Moon phases. Existing research studies on students' alternative conceptions about these phenomena have been the starting point to develop an open questionnaire submitted to 250 secondary school students. A content-based categorization of students' answers has been used to develop an initial learning progression of the three phenomena. Then, a two-tier multiple-choice questionnaire was designed to validate and improve the initial learning progression. This questionnaire will be submitted to about 200 secondary students of different school levels (13-14 years old and 18-19 years old). Findings will be useful to move further research about students' understanding of astronomical phenomena. Moreover, they will provide useful insights about how to develop learning progression in different science areas.

Building a Learning Progression for Chromosome Segregation in Genetics Using Variation Theory from Phenomenography

Stanley Lo, Northwestern University

Stephanie Kim, Northwestern University

Su Swarat, California State University

Fullerton Gregory Light, Northwestern University

Chromosome segregation is a central phenomenon in genetics and is one of the most important yet difficult concepts for students. Most studies on how students learn genetics have focused on the K-12 level. In this paper, we explore how students understand chromosome segregation and describe the process of building a learning progression for this concept at the undergraduate level using variation theory from phenomenography. Clinical interviews were employed to examine students' conception of chromosome segregation. Data analysis focused on the different ways that students conceptualize this biological phenomenon and identified the variations among these conceptions that highlight their differences. For example, we discovered three distinct conceptions in how students understand genetic recombination: conceptual (i.e. phenotypic differences from parents), mathematical (i.e. defined frequency from crosses), and

symbolic (i.e. genotypic combinations of alleles). A major finding is the disconnection among different conceptions that students used to describe the phenomenon, indicating that students had difficulty integrating the multiple modes of representation of chromosome segregation employed in instruction. We believe that these findings and our approach can shed light on possible ways to build a learning progression for chromosome segregation at the undergraduate level.

Change of Students' Conceptions - A Longitudinal Study in Chemistry Education

Barbara Hank, University of Applied Sciences Munich

Jutta Maegdefrau, University of Passau

A multitude of studies has shown that students enter science classes with conceptions derived from earlier experiences. These conceptions are often inconsistent with the scientific views taught at school and can impede learning processes. A promising approach to overcome difficulties arising from the incompatibility of conceptions is the application of context-based curricula in which authentic problems are used to introduce and develop scientific conceptions. The main objectives of this study were to describe the development of students' conceptions of combustion and to clarify whether context-based teaching is superior to traditional teaching in regard to the development of scientific conceptions. The longitudinal study employed a quasi-experimental design. One group of students was taught using "Chemie im Kontext", a context-based curriculum; the others experienced traditional chemistry courses. More than 900 students from 12 middle track schools in Germany participated in the study. Students' conceptions of combustion were assessed using open-ended questions. The questionnaire was administered as pre-, post- and follow-up-test to show the development of students' conceptions. Results indicate that learners in both groups were able to develop their conceptions towards more scientific understanding. The students attending the context-based courses showed significantly better results.

Assessing Changes in Categorization after Exposure to Science: The Re-Cat Task

Stella Vosniadou, National and Kapodistrian University of Athens

Anna Chountala, National and Kapodistrian University of Athens

Despina Lepenioti, National and Kapodistrian University of Athens

Kalliopi Eikospentaki, National and Kapodistrian University of Athens

A re-categorization task designed with E-prime was developed to investigate categorization changes in children and adults after exposure to science learning. Ninety seven elementary school children (grades 4, 5 & 6) and forty three college undergraduates were presented with thirty four concepts from 4 subject matter areas (physics, biology, mathematics and epistemology) in two categorization conditions: In the Initial condition the participants had to decide between a naïve and an anomalous category while in the Scientific condition they had to decide between the naïve and a scientific category. We hypothesized that initial categorizations will be more accurate and faster than scientific categorizations. The results confirmed our hypotheses indicating that considerable changes in ontological categories happen in middle childhood and that initial categories are more easily accessible even for college undergraduates for scientific concepts introduced in the elementary school curriculum.

PAPER SESSION IIIB (ROOM B)

NON-FORMAL REASONING IN SCIENCE: ANALOGY, METAPHOR AND EMBODIMENT

Chair: Hans Fuchs, Zurich University of Applied Sciences at Winterthur

Varying Use of Conceptual Metaphors Across Levels of Expertise and Contexts of Language Use in Thermodynamics

Fredrik Jeppsson, Swedish National Graduate School for Science and Technology Education
Jesper Haglund, Swedish National Graduate School for Science and Technology Education
Tamer Amin, American University of Beirut

Many studies have previously focused on how people with different levels of expertise solve physics problems. In early work, focus was on characterizing differences between experts and novices and a key finding was the central role that propositionally expressed principles and laws play in expert, but not novice, problem solving. A more recent line of research has focused on characterizing continuity between experts and novices at the level of non-propositional knowledge structures and processes such as image-schematic knowledge structures, imagistic simulation and analogical reasoning. This study contributes an emerging literature addressing the coordination of both propositional and non-propositional knowledge structures and processes in the development of expertise. Specifically, in this presentation we compare problem solving across two levels of expertise - undergraduate students of chemistry and PhD students in physical chemistry – and characterize differences in how conceptual metaphors are used (or not) to coordinate propositional and non-propositional knowledge structures in the context of solving problems on entropy.

Embodied Cognition as a Powerful Framework for Teaching and Learning in Micro- and Macrocsm

Kai Niebert, Leuphana University Lueneburg

In searching for fruitful conceptual change strategies, the role of external representations came into the focus of science education researchers. Based on the theoretical framework of embodied cognition, we developed and evaluated representations on phenomena located within the microcosm (cell division) and the macrocosm (climate change). Based on teaching experiments with 50 students we show that students and scientists use imaginative thinking to understand the imperceptible world of cell division and climate change. This imaginative understanding is achieved by conveying the structure of embodied schemata to abstract science concepts: To understand the growth of cells both scientists and students refer to a division schema, but map different parts of the schema on cell division. In the case of climate change scientists and students use schemata of containers, balances and man-made vs. natural and combine them differently. To analyse students' and scientists' sources of understanding and their conceptual development we introduce the concept of meso-, macro-, and microcosm.

Analogies and Metaphors in Teaching Maxwell's Equations: Analyzing the Didactic Discourse of a Distinguished Physics Professor

Ricardo Karam, University of Hamburg

In this work, I describe the extensive and rather unusual use of analogies and metaphors present in the electromagnetism lectures given by an experienced physics professor. The analysis of a 60-hour introductory course given to physics majors shows that analogical and metaphorical reasoning play a decisive explanatory role in his didactic discourse. Among the motivations for conducting this case study is the students' extremely positive evaluation of the quality of this professor's explanations over more than 30 years. The examples presented here will focus on the instructional strategies used by him to explain the meaning of important mathematical operations (e.g. div, curl, grad) involved in Maxwell's equations. Finally, his justifications for such a frequent use of analogies and metaphors – assessed during semi-structured interviews with the professor – are presented and discussed. The findings of this research support the overall claim that the understanding of abstract concepts is ultimately grounded in experiential image schemas (Lakoff, 1990) and that metaphorical representation of concepts is an important indicator conceptual change (Amin, 2009).

Nested Levels of Processes in Expert Learning and in Classroom Teaching Strategies

John Clement, University of Massachusetts, Amherst

The first part of this study analyzes data from video-taped protocols of experts thinking aloud about explanation problems. Expert learning processes were identified at four time scale levels. These are compared to learning processes that teachers attempt to foster in whole class discussions in science in part two of the study and some important parallels are identified. Examples of expert processes observed at the level of non-formal reasoning were: analogies, concept differentiation, Gedanken experiments, and the construction and running of visualizable explanatory models. Cycles of model generation, evaluation, and modification that utilized the non-formal reasoning processes above were seen at a higher time scale level. Through classroom video studies, such processes and sub-processes were compared to learning processes that experienced teachers attempt to foster in whole class discussions. Important similarities to strategies used by two high school physics teachers and a middle school biology teacher are identified. By using a nested levels of processes perspective, we can attempt to conceptualize an expanded and more transparent view of learning and conceptual change processes. Comparisons to expert reasoning can improve our ways of describing the reasoning of students and teachers during discussions, and help in identifying newly described teaching strategies.

PAPER SESSION IIIC (ROOM C)

MEDIATION AND SOCIAL DYNAMICS IN CONCEPTUAL CHANGE

Chair: Xenia Vamvakoussi, University of Ioannina

'Zero-Order' Modelling Steps: Looking for a Comprehensive Ecology of Changing Minds

Paolo Guidoni, Dipartimento di Scienze Fisiche, Università Federico II, Napoli, Italy

'Conceptual Change' (C.C.) easily evokes both inclusive frameworks and particular aspects of the complex, humanly natural, everlasting evolution of individual cognitive dynamics. Within such a bundle of correlated processes, evolving cognitive potentialities and interacting supports and constraints from culture and environments reciprocally interfere, eventually coagulating into quasi-resonant, quasi-stable cognitive configurations. Several research strands investigate

C.C. specific aspects by specific methods, producing specific modeling types: resulting ‘theories’ partially overlap and partially diverge, yet missing the comprehensive insights necessary - just as an example - to allow for planning effective and efficient teaching strategies (e.g. in STEM education). A schematic, ‘zero-order’ model of cognitive dynamics is (partially) outlined, as actually able to: (i) account for most evident features of what happens at short, medium and long term in classrooms observed along hours, months, years of interacting culture-vs-cognition; (ii) plan what might happen, according to modeling hypotheses which emerge, evolve, get validated rejected and eventually restructured in real time, parallel to ‘practices’; and (iii) consolidate correlated, effective and efficient approaches to cultural transmission within different STEM areas. ‘Practical’ implications are implicit within modeling bootstrapped from systematic contextual variations looking for more-resonant outcomes; ‘theoretical’ ones challenge strategic integrations, involving different approaches and insights.

Conceptual Change in ‘Linear’ Thinking: Experiencing Elastic Deformations in Third Grade

Maria Mellone, Università degli Studi Federico II, Naples, Italy

Paolo Guidoni, Università degli Studi Federico II, Naples, Italy

Ciro Minichini, Università degli Studi Federico II, Naples, Italy

Michela Esposito, Università degli Studi Suor Orsola Benincasa di Napoli, Naples, Italy

Fabrizio Manuel Sirignano, Università degli Studi Suor Orsola Benincasa di Napoli, Naples, Italy

We used a ‘cognitive resonance’ model to frame, to plan and to guide an educational path in two third grade classrooms, with the aim to lead pupils to control the ‘linear’ (proportional-and-additive) relationship shaping the behavior of a spring when ‘stressed’ by hung weights. The recognized contribution of both formal structures to the interpretation of elasticity data was the conclusion of teaching long-term design initiated by the external observation of analogical ‘kitchen’ weighting scales, followed by their disassembling and by the exploration-understanding of their internal mechanical structure. The episode was concluded after production and discussion of a variety of hypotheses about the various aspects of the ‘mechanism’, with children working (in groups of three) to take, to organize and to interpret quantitative data on springs’ performances. Through the cognitive model of resonance we will discuss and analyze the teaching design and re-design developed in order to produce resonance between pupils’ cognition and the cultural model of linearity for the spring behavior, trying to follow pupils’ conceptual changes occurred during the path.

Cultural Environment and Mediated Conceptual Change

Nadia Douek, ESPE- University of Nice

As a contribution to research on conceptual change and its educational implementation, I will present an integrated framework, derived from: Vergnaud’s definition of conceptual field (whose components are: reference situations, operational invariants and representations); and Vygostky’s elaboration on everyday concepts and scientific concepts, and their dialectical relationship in teaching-learning contexts. This framework aims at capturing potential socio-cultural levers of conceptual change and their activity components, at the same time providing a tool to observe and analyze conceptual change within activity, and to conceive educational settings to favor it. To illustrate and discuss this use of the framework, I will present an experimental didactical setting conceived according to it, and elements of analysis of conceptual

changes performed in that context. The experiment took place in a rural class in Burkina Faso to develop the conceptualization of mass and related mathematical and physical concepts towards a scientific mode and in relation to students' socio-cultural and body experience. In particular, everyday practices of measuring quantities of cereals and related tools were the starting points and references for the didactical sequence.

Conceptual Change in Group Discussion: An Exploratory Study

Laura Branchetti, University of Palermo

Francesca Morselli, University of Torino, Italy

In this contribution, we discuss conceptual change in mathematics, as it takes place during social interaction in group-work in the classroom. We rely on a socio-cultural perspective, according to which the learning of mathematics takes place in a social context (Radford, 2006, 2011). We argue that conceptual change, as part of mathematics learning, may be a social act deeply related to the subjectivities of students involved in group activity. Students' interactions are analyzed by means of an integrated frame, encompassing the construct of subjectification (Radford, 2008), identity (Sfard & Prusak, 2005) and rational behavior (Boero & Morselli, 2009). The analysis shows that, during the group activity, there is a continuous interplay between social interaction and individual identity; each student, by means of his rationality, engages in the construction of coherent structures. Conversely, each individual contributes to the construction of group coherent structures. Thus, a sort of "group-coherence" turns out to be a necessity in the subjectification process. In both processes, (change at individual level and construction of a group coherence) communicative rationality plays a key role.

PLENARY LECTURE II (5:00 – 6:30 PM) (ROOM A)

Chair: Stella Vosniadou, National and Kapodistrian University of Athens

Promoting Reasoning and Conceptual Change through Argumentation: Challenges and Responses

Clark Chinn, Rutgers University

In this presentation, I discuss four core challenges to promoting conceptual change and epistemic growth in middle-school science classes. I draw on my research with the PRACCIS (Promoting Reasoning and Conceptual Change in Science) project with Ravit Duncan and colleagues; this project aims to promote students' reasoning ability and conceptual understanding through model-based inquiry, with argumentation featured as the central discourse. Data come from two implementations of PRACCIS in a total of 44 middle-school classes (with 12 and 13 year olds) taught by 9 teachers. The first challenge is the problem of underdetermination. Our research suggests that, in the practical realities of science classes, model choice is underdetermined by evidence, so that evidence-based arguments cannot be decisive. A second challenge is establishing social norms for reasoned argumentation as the core discourse. Third is the problem that students must succeed in simultaneously changing both epistemic practices and content understanding. Finally, teachers often have difficulty trusting students to take the lead in argumentation. I present data bearing on each of these challenges, and suggest ways in which effective design of inquiry environments can successfully address them. One of the design features that we have found helpful is the use of public epistemic criteria generated and refined by students.

DAY THREE

THURSDAY, AUGUST 28TH, 2014

SYMPOSIUM SESSION II (8:30 – 10:30 AM)

SYMPOSIUM IIA (ROOM B)

ON THE NATURE OF CONTINUITY OR DISCONTINUITY BETWEEN LAY AND SCIENTIFIC CONCEPTUALIZATIONS IN PHYSICS

Organizers: Hans Fuchs, Institute of Applied Mathematics and Physics, Zurich University of Applied Sciences at Winterthur, Switzerland

Federico Corni, Department of Education and Humanities, University of Modena and Reggio Emilia, Italy

Discussant: Maria Giuseppina Bartolini, Department of Education and Humanities, University of Modena and Reggio Emilia, Italy

Chair: Jesper Haglund, Swedish National Graduate School for Science and Technology Education

In this symposium, we wish to discuss the question about the extent of continuity between everyday and scientific concepts in physics. We claim that in macroscopic physical systems and processes, continuity is much stronger than is commonly accepted in school science and in science education research. This claim is supported by our research in physics teaching, conceptual structures in physics and the human mind. For example, modern continuum physics uses a conceptual integration network (i.e., a figurative metaphoric structure) that is closely related to everyday conceptualizations of the physical world. We will present evidence for strong continuity in cases of primary science education (and the training of primary school teachers) and college physics courses for engineers. We will stress, however, that continuity of underlying conceptualizations alone does not make learning of a science simpler. The task of education shifts from one where we—however gently—bend human minds to conform to school science to one where students learn to use their own conceptual networks and make them productive. One particular educational approach for accomplishing this is the progressive differentiation of aspects of perceptual gestalts of physical phenomena. These examples of continuity between lay and scientific conceptualizations in physical science call for a careful reevaluation of models of conceptual change. Indeed, we prefer to think of conceptual growth and differentiation rather than change. It is not clear, however, how far this confluence of scientific and everyday conceptualizations can go in quantum physics and in the science of complex systems. Narratologists commonly assume that narrativity breaks down in quantum and complex systems. Since narrativity of science seems to be a necessary ingredient for connecting everyday reasoning to science, only further research can show what kind of conceptual change is necessary for the learning of quantum physics.

Contributed papers:

When Science Needs Conceptual Change—What Thermodynamics Tells Us About Continuity

Hans Fuchs, Institute of Applied Mathematics and Physics, Zurich University of Applied Sciences at Winterthur, Switzerland

How Far Does Continuity Go in Conceptualizations of Forces of Nature?

Federico Corni, Department of Education and Humanities, University of Modena and Reggio Emilia, Italy

Enrico Giliberti, Department of Education and Humanities, University of Modena and Reggio Emilia, Italy

From Forces of Nature to the Physics of Dynamical Systems

Elisabeth Dumont, Institute of Applied Mathematics and Physics, Zurich University of Applied Sciences at Winterthur, Switzerland

Francesca Venturini, Institute of Applied Mathematics and Physics, Zurich University of Applied Sciences at Winterthur, Switzerland

Werner Maurer, Institute of Applied Mathematics and Physics, Zurich University of Applied Sciences at Winterthur, Switzerland

Breakdown of Narrativity—Is it Impossible to Relate Quantum Physics and to a Narrative Mind?

Gabriele Ceroni, University of Bologna, Italy

SYMPOSIUM IIB (ROOM C)

THE DEVELOPMENT OF QUANTITATIVE REASONING: DISPOSITIONS AND BIASES

*Organizers: Jake McMullen, University of Turku, Finland
Wim Van Dooren, University of Leuven, Belgium*

Discussant: Rafael Núñez, University of California, San Diego

Chair: Panayiota Kendeou, University of Minnesota

Quantitative reasoning plays major roles throughout the development of mathematical skills, and takes many forms. This symposium aims to account for a number of pivotal points in the development of reasoning about quantities and their relations, and in doing so present an integrated image of different aspects of the role quantitative reasoning plays in mathematical development. After ten years of intense study of conceptual change with mathematical concepts (see Vosniadou & Verschaffel, 2004), a broader perspective has been called for that looks over a wider range at the antecedents and consequences of learning keystone mathematical concepts, such as rational numbers. Thus, this collection of studies looks across the stages of mathematical developmental, beginning with early primary (Nunes et al.), and continuing to late primary (Degrande et al. and McMullen et al.) and secondary (Bempeni et al.) levels, at a number of key aspects of quantitative reasoning, including proportional relations (Degrande et al. and Nunes et al.), quantitative relations (Degrande et al. and McMullen et al.) and rational numbers (McMullen et al. and Bempeni et al). To this end, we present four studies investigating different aspects of students' quantitative reasoning across the developmental timeline. First, Nunes et al. investigate how children's understanding of proportional relations rely on scalar or

functional distinctions through the use of parallel line diagrams as proposed by Streefland. Second, Degrande et al. present a study of 3rd to 6th grade students' spontaneous use of quantitative analogical aspects of incomprehensible word problems, specifically their perceptions of additive or proportional relations. Third, McMullen et al. investigate the role of spontaneous focusing on quantitative relations in predicting conceptual and procedural knowledge of rational numbers. Finally, Bempeni et al., will look at the interplay between conceptual understanding of and procedural fluency with rational numbers in 7th and 9th graders.

Contributed papers:

“That Sounds Greek to Me!” Primary Children’s Additive and Proportional Responses to Unreadable Word Problems

Tine Degrande, University of Leuven, Belgium
Lieven Verschaffel, University of Leuven, Belgium
Wim Van Dooren, University of Leuven, Belgium

Different Perspectives on Multiplicative Relations

Terezinha Nunes, University of Oxford
Peter Bryant, University of Oxford
Laura Gottardis, University of Oxford
Maria-Emmanouela Terlektsi, Oxford Brookes University
Akhila Pidah, University of Oxford

Seventh and Ninth Graders’ Conceptual and Procedural Knowledge of Fractions: What Changes with School Experience?

Maria Bempeni, University of Ioannina, Greece
Xenia Vamvakoussi, University of Ioannina, Greece

Spontaneous Focusing on Quantitative Relations Predicts Conceptual but not Procedural Knowledge of Rational Numbers

Jake McMullen, University of Turku, Finland
Minna M. Hannula-Sormunen, University of Turku, Finland
Erno Lehtinen, University of Turku, Finland

PAPER SESSION IV (11:00 AM – 1:30 PM)

PAPER SESSION IVA (ROOM A)

CONCEPTUAL CHANGE IN MATHEMATICS EDUCATION

Chair: Wim Van Dooren, University of Leuven

Characterizing Conceptual Changes in Algebraic Acquisition

Judi Humberstone, University of Melbourne
Robert Reeve, University of Melbourne

To determine the ways in which algebraic equivalence understanding is related to the development of subsequent algebraic abilities 135 12-year-olds solved arithmetic (canonical and non-canonical) and algebraic equations on three occasions at nine-month intervals. In Phases 2 and 3, variable-use was assessed by the ability to map symbolic expressions onto simple phrases (e.g., five less than t), and algebraic word problems (i.e., the embedded equation included variables both sides of the equals sign). In Phase 3, students completed a Use of Variables Test comprising twenty problem items representing four levels of understanding variables. Latent Gold cluster analysis, based on non-canonical (e.g., $17 = 3c - 4$) equation problem-solving success in the Phase 3, revealed four ordered groups (n = 11, 33, 25 and 66) consistent with conceptual change processes underpinning the transition from arithmetic to algebraic understanding of the equals sign. The groups were systematically related to progressive changes in understanding variables and algebraic mapping abilities. Overall, the research highlights the importance of the early identification of individual differences in components of algebraic competence, and has important pedagogical implications for algebra instructional design.

The Development of Conceptual Knowledge of the Density of Rational Numbers

Mikko Kainulainen, University of Turku
Jake McMullen, University of Turku
Erno Lehtinen, University of Turku

The learning of rational numbers has repeatedly been proved to be a process that requires considerable conceptual change. A longitudinal study is presented in which the early development of the understanding of the dense nature of rational numbers in 4th–6th grade students is investigated. The participants (n = 240) were tested in the beginning and in the end of their semester, through a rational numbers test that included questions about the density of fractions and decimals. Consistent with previous studies, the results showed that the idea of discrete numbers was very strong in the great majority of the participants. The results also showed significant difference between the different types of rational numbers (fractions and decimals) in the understanding of density. The conceptions of density were generally more advanced within decimals than within fractions. It is argued that the understanding of density with decimal numbers for many students appears to act as an important gateway towards a more complete understanding of density. These findings are interpreted in the framework of conceptual change and recent findings in the field of cognitive development.

Artefacts and Conceptual Change: A Case Study in Geometry

Giorgio Bolondi, Alma Mater Studiorum, University of Bologna
Federica Ferretti, Alma Mater Studiorum, University of Bologna
Alessandro Gambini, University of Ferrara

We discuss the result of a teaching experiment with classes of children from 7 to 11 years old, where a particular artefact, the Lénárt Spheres, is used as a tool for investigating conceptual changes in the process of associating a name to a geometrical object, namely the circumference. This process can usually take the form, in mathematical activity, of a denomination, a designation, a description, a denotation or (in a mature and formal organization of mathematical knowledge) of a definition. These are epistemologically and cognitively different actions, and the switching from one to another may be the result of a conceptual change of the student. We

show how this change develops through a comparative geometry activity performed in a learning environment (spherical geometry) where the usual relations between well known geometrical objects, their representations and their properties are de-structured and reorganized. Both individual and cooperative behaviors and actions of children- including their use of natural language- are examined, in order to have a picture of their processes implied in the task of associating the name “circumference” to the geometrical object.

Investigating The Role of the Object Collection Metaphor in Early Number Concepts

Andrew Manches, University of Edinburgh

Mihaela Dragomir, University of Edinburgh

Children’s developing number concepts may be supported by different conceptual metaphors e.g. Object Collections or points along a line. Understanding the roles played by different metaphors may help predict conceptual demands and inform choices of instructional material. This paper presents an exploratory study investigating the role of the Object Collection metaphor in two early concepts of numerical relations: Commutativity and Compensation. In the study, ten student teachers were asked to explain the relationship between two addition sums with equal totals (1+8 and 8+1 for Commutativity; 1+8 and 2+7 for Compensation). In explanations, seven out of ten participants used representational gestures, which often traced pathways between two spatial groups. Moreover, five participants formed a pinch/grasp hand form despite absence of physical representations. Notwithstanding several methodological issues discussed, the study provides tentative evidence for the role of the Object Collection metaphor in adults’ concepts of the number relationships investigated.

Direct Instruction as More Effective Than Self-Learning in a Real Classroom Algebra Introduction

Esther Ziegler, Center for Research on Learning and Instruction, ETH Zurich, Switzerland

Elsbeth Stern, Center for Research on Learning and Instruction, ETH Zurich, Switzerland

Self-learning methods are widely accepted in education communities and many teachers rebuild their teaching toward more self-learning activities. However, there is increasing evidence for substantial effects of direct instruction. The aim of this study was to compare a self-learning with a direct-instruction setting in algebra. In the self-learning group, 80 sixth-graders processed a program with worked examples and self-explanation questions that prompted students to extract the principles by themselves. In the direct-instruction group, 85 sixth-graders were given an introduction at the blackboard by the teacher who guided the deriving of the principles. There were four 2-hour sessions with 9 introduction units. The results showed advantages of direct instruction for conceptual understanding in the short and medium term, however, no longer ten weeks later. For the ability to solve transformation problems, we could not show advantages of direct instruction, but the means went in direction of a benefit for direct instruction.

PAPER SESSION IVB (ROOM B)

**CONCEPTUAL CHANGE IN SOCIAL DOMAINS:
RELIGION, HISTORY, PSYCHOLOGY, PEDAGOGY AND HEALTH WORK**

Chair: María Pilar Jiménez-Aleixandre, Universidade de Santiago de Compostela

When The Truth isn't What Actually Happened: Student Conceptions of Truth and Epistemic Practices in Orthodox Jewish Bible Study

Moshe Krakowski, Yeshiva University

David Block, Yeshiva University

This paper investigates student conceptions of truth in the context of Orthodox Jewish Bible study. We argue that a simple account of students' view of religious truth as a unitary and stable construct is inadequate. Instead, truth, which is a fundamentally epistemological concept, must be understood in terms of the epistemological resources students draw on when engaging in epistemic activities. When the epistemic resources demanded by an interview task do not match those of the epistemic activity in which the concept is expressed, students will try to generate answers amidst confusion and disagreement. This suggests that accounts of epistemic concepts must attend to the epistemic resources associated with authentic knowledge practices for the domain in question.

History Students' Organization of Historical Knowledge While Interpreting Visual Sources

Marjaana Penttinen, University of Turku

Markus Nivala, University of Regensburg

Arja Virta, University of Turku

This study explores the route towards expertise in history through history students' organization of historical knowledge in the context of interpreting visual sources. The theoretical background bridges the often applied, two-level categorization of historical concepts (e.g., Lee, 2005; 2011; Walsh, 1967) with the encapsulation theory developed in the context of medical expertise (e.g., Boshuizen & Schmidt, 1992; Schmidt & Rikers, 2007). The aim is to examine (a) how history students define and depict a key organizer of historical knowledge, time, and (b) to what extent they use encapsulated, high-level historical concepts while interpreting visual sources. In the study, 23 history students determined themes for two series of historical images and were interviewed on how they viewed and interpreted them. As a first result, four categories for depicting time in relation to history were identified, ranging from the traditional timeline to abstract networks of historical phenomena. The research questions will be answered in full in the conference presentation. In general, research on the development of historical knowledge is needed to aid the teaching of history from elementary school to the university level.

Theorizing in Practice - A Comparison of Problem- and Error Based Instructional Strategies for Inducing Conceptual Change in Teacher Education

Martin Klein, Saarland University, Department of Education

Kai Wagner, Saarland University, Department of Education

Robin Stark, Saarland University, Department of Education

Teacher students have severe problems with the application of scientific knowledge to complex school situations and harbor negative attitudes toward theories in the social sciences, which impede conceptual change. To demonstrate the usefulness of scientific knowledge in the domain of pedagogy, which is endorsed by experts in teacher education research, the application of theoretical and empirical scientific knowledge to complex school situations has to be fostered systematically to promote conceptual change in teacher education. Two case-based learning environments, based on productive failure and learning from instructional errors, respectively, were developed, aiming at improving students' competence in the explanation of complex school situations on the basis of scientific knowledge. Both learning environments led to students using significantly more scientific concepts in their explanations. However, students in the error-based condition acquired additional "negative knowledge" which enabled them to formulate explanations nearly as good as those in the problem-based learning environment and to identify errors in a given explanation; outperforming the problem-based learning environment in this task. Therefore, a learning environment based purely on instructional errors will be tested next.

Supporting Conceptual Change for Community Health Workers: The Role of Discourse and Educational Media During Household Visits

Jim Slotta, University of Toronto

Duncan Andrew, Thandanani Children's Foundation

Robert Inglis, Jive Media Africa

Nokhaya Makiwane, Sinomlando Centre for Oral History and Memory Work

Jessica Chan, Northern Ontario School of Medicine

Lisa Butler, Boston Children's Hospital, Harvard Medical School

This paper reports on a program of research that applies a perspective of learning through discourse and situated reflection to create practice-based conceptual change for community health workers (CHW) in South Africa. In resource-limited countries, CHW provide basic health services to their communities, despite minimal training, low levels of support, and limited knowledge of health topics or practices. We describe our design of a mobile technology environment that supports CHW during visits to HIV affected households. Community Healthworker Assistive Technologies (CHAT) is a handheld tablet-based environment that centers on carefully designed digital media resources (videos and animations) that target relevant health topics, promoting situated discourse and learning for both CHW and household members. CHAT was developed through a participatory design method, to fit within the existing ecology of work undertaken by an established Non Governmental Organization partner. We report on the theoretical perspective, the design process, and the current research study.

PAPER SESSION IVC (ROOM C)

**CONCEPTUAL CHANGE IN SCIENCE EDUCATION: INNOVATIONS
IN INSTRUCTION AND ASSESSMENT**

Chair: Lucia Mason, University of Padova

The “Parallel” Globe: A Tool for Conceptual Change in Astronomy

Enrica Giordano, Physics Department, University of Milano-Bicocca

Nicoletta Lanciano, Mathematics Department, University of Rome "La Sapienza"

Sabrina Rossi, Physics Department, University of Milano-Bicocca

Many researches on conceptual change are devoted to astronomical topics: Earth’s shape, lunar phases, and seasons, just to mention some. Our interest is in understanding problems which arise in connecting the local point of view with the heliocentric interpretation and to empirically validate possible instructional interventions to overcome these difficulties. We have found a widespread confusion of North vs. up, South vs. down, local inclination of a globe vs. the Earth’s position in space, observed motion of the Sun above the local horizon and its variations along the year vs. the Earth’s revolution around the Sun. These difficulties are not equally shared among children and adults. The situation in some sense is worse among university students than primary school children suggesting that the traditional teaching sequence about astronomy is producing unexpected misconceptions. We designed and tested a three-step route to help learners to connect their local observers’ point of view with the heliocentric one, passing through an intermediate step, where they observe what is happening simultaneously in different parts of the Earth. This global, geocentric view makes use of a “parallel” (omothetic) globe. We will present the instrument and results of our empirical projects in different contexts.

How is Conceptual Change Different with A Focus on Twenty-first Century Science Knowledge?

Nancy Songer, The University of Michigan

In the 1980s, science educators such as Rosalind Driver chronicled conceptual change in science. Recently, science education research has shifted to an emphasis on developing 21st century learning skills within science and other disciplines. This shift presents a need for new conceptual change research such as: How is conceptual change focused on twenty-first century science knowledge similar or different to conceptual change of the past? Our data consisted of pre and posttest information from 350 secondary students using an eight-week curricular unit designed to foster conceptual change associated with twenty-first century science knowledge of climate change. Our results suggest the need for articulate and challenging work to foster conceptual change of new science knowledge, including new pedagogy and coding rubrics that articulate scaffolds and teacher moves to help students provide mechanisms to illustrate the nature of relationships between variables rather than merely recognizing a relationship. Our work has resulted in new coding rubrics (with new criteria and illustrative examples), outcomes, and reflections to help us characterize and better understand conceptual change in our time.

Using Web-Based Interactive Tools for Information to Assess Conceptual Change

Milo Koretsky, Oregon State University

Debra Gilbuena, Oregon State University

Bill Brooks, Oregon State University

Edith Gummer, WestEd

We present a case study of a web-based interactive learning tool that affords data collection to provide information regarding students' conceptual understanding. The tool, the Concept Warehouse, was developed with a goal of facilitating the implementation of concept-based pedagogy. It houses concept questions, concept inventories, and interactive virtual laboratories. We provide a description of instances of documented use where gathering information on student conceptual understanding was the goal of instructors or researchers. In addition we provide an account of the parts of the development process that provide the foundation for these instances. We use multiple data sources to provide triangulation and a holistic view, including: development documentation, interviews (with the developers, researchers, and instructors), observations of use (when available), reports, published articles, and draft papers that include use of the tool. Five instances were identified. Three instances include analysis of individual responses to concept questions or interactive virtual labs. Two instances of course level analyses are described which compare effects on conceptual learning gains between electronic and in person delivery modes. The flexibility built into the tool architecture and the collaborative relationship with users are identified as key components.

Mapping High School Students' Understanding of "Big Ideas" of Chemistry in the Context of Computer-based Models and Model-Based Assessments

Noemi Waight, University at Buffalo, SUNY

Xiufeng Liu, University at Buffalo SUNY

Melinda Whitford, University at Buffalo, SUNY

This study reports on a mixed quantitative and qualitative study on the fine-grained analysis of students' understandings of three big ideas of chemistry phenomena—matter, energy and models—in the context of computer-based models and model-based assessments. Students' reasoning patterns of big ideas were examined via results from model-based assessments (gases, acids and bases, solutions), classroom observations and follow-up student interviews. Assessments results and student explanations revealed consistent level 1 and 2 understandings. Correlation coefficients for all three assessments revealed statistically significant positive correlations indicating that students' explanations during follow up interviews were consistent with their assessment results. Students articulated more robust understandings of matter/energy when compared with models; notions of models reflected literal interpretations of the function of models. Finally, students' reasoning was organized to reflect two major categories: explanations that explicitly referenced macro and submicro features of the models versus standalone explanations that did not draw on model representations. It was the case that more sophisticated explanatory (vs. descriptive) reasoning was evident when explicit features of the models were referenced. These results have implications for novice learners. Demarcating their nuanced fine-grained understandings is essential before we attempt to attach expectations defined by expert knowledge and capabilities.

Quantum Mechanics and Conceptual Change: An Educational Proposal Based on the Feynman Approach

Massimiliano Malgieri, University of Pavia, Physics department

Pasquale Onorato, University of Pavia, Physics department

Anna De Ambrosis, University of Pavia, Physics department

The teaching of quantum mechanics is a complex educational problem, in which general questions regarding science teaching are intertwined with epistemological and foundational issues peculiar to quantum physics. In this paper, we describe an educational proposal based on the Feynman sum over paths approach, aimed at guiding students in the process of conceptual reconstruction. Taking the phenomenology of light as our point of departure, we use evidence from relatively recent experiments in quantum optics expose the radical incompatibility between the classical and quantum worldviews. Through an early presentation of modern and more convincing evidence for such incompatibility, we hope to make a step forward in preventing student from producing an hybrid classical-quantum conceptual picture. Furthermore, the approach based on Feynman's alternative paths and processes enables us to present students with an epistemologically clear and intelligible perspective on quantum physics, providing an explanatory framework for traditionally problematic concepts, such as wave particle duality, the uncertainty principle and the role of measurement. The general lines of this approach have been proposed to teacher learners; preliminary results will be available for discussion at the conference.

PAPER SESSION V (3:00 – 4:30 PM)

PAPER SESSION VA (ROOM A)

TEXT PROCESSING AND COMPREHENSION FOR CONCEPT LEARNING

Chair: Barbara Pecori, University of Bologna

An Eye-Movement Analysis of Integrative Processing and Conceptual Learning from Illustrated Science Text

Lucia Mason, University of Padova, Italy

Maria Caterina Tornatora, University of Padova, Italy

Patrik Pluchino, University of Padova, Italy

Successful comprehension of an illustrated text relies on meaningful integrative connections between verbal and graphical information. This study used eye-tracking methodology in the school setting to examine students' processing of text and graphics while reading an illustrated science text on the food chain, and its contribution to conceptual learning from text. Forty-three seventh graders participated. After reading the illustrated text, they completed various tasks: verbal and graphical recalls, multiple-choice and open-ended questions for text-based factual knowledge, and transfer of knowledge. Eye-movement indices of integrative processing during the second-pass reading were computed. The look-from text to picture fixation time is the duration of all regressive fixations on the picture while re-reading a text segment. The look-from picture to text fixation time is the duration of all regressive fixations on the text while re-inspecting a picture segment. A cluster analysis using the eye-movement indices revealed two

patterns of visual behavior varying for the level of integrative processing. These patterns predicted students' performances in the two recalls and in the transfer, after controlling for reading comprehension and prior knowledge. The greater the integrative processing of verbal and graphical information during reading, the higher the scores of less deep and deeper conceptual learning.

Inferences at Encoding and Retrieval and Their Contribution to Learning from Refutation and Expository Text

Irene-Anna Diakidoy, University of Cyprus

Thalia Mouskounti, University of Cyprus

Argyro Fella, University of Cyprus

The purpose of this study was to examine the comprehension processes and outcomes and their contribution to learning from refutation and expository text. The study employed a think-aloud methodology to examine conceptual change and inferential processes during the encoding of text information and a recall task to examine memory for text and inferences in retrieval. Students were pretested on their knowledge about the concept of energy and read either a standard expository text or a corresponding refutation text that refuted three misconceptions in addition to presenting information about energy transformations and conservation. A delayed posttest, same as the pretest, was administered to measure learning gains. Prior knowledge was found to positively influence the generation of inferences both at encoding and retrieval. Text structure, however, had a positive effect on the generation of inferences in retrieval only. Inferences in recall were also the only significant predictor of learning from text. These findings are discussed in relation to their implications about the nature and the timing of the refutation text effect in learning and the restructuring of misconceptions.

The Knowledge Revision Components (KReC) Framework

Panayiota Kendeou, University of Minnesota

Edward J. O'Brien, University of New Hampshire

Kendeou and O'Brien (in press) proposed the Knowledge Revision Components (KReC) framework that encompasses five key principles that guide knowledge revision during reading. These principles are encoding, passive activation, co-activation, integration, and competing activation. In this presentation, the framework and its principles will be presented along with a set of three experiments that were designed to provide further evidence for the revision mechanism proposed by KReC using three different paradigms: reading times, eye-tracking, and think-alouds. What the KReC framework contributes to the existing literature is the fundamental underpinnings of knowledge revision at the level of basic processes and mechanisms, independent of the grain size or coherence level of the representation of prior knowledge. Specifically, KReC outlines basic comprehension processes and text factors that can be accentuated to increase the potential for successful knowledge revision during reading, by systematically mitigating the interference from prior incorrect knowledge.

PAPER SESSION VB (ROOM B)

CONTRASTING AND DEVELOPING MODELS: KNOWLEDGE-IN-PIECES, COMPLEXITY AND CONCEPTUAL CHANGE

Chair: Nadia Douek, ESPE, University of Nice

Intuitive Rules vs. P-Prims: Same or Different?

Haim Eshach, Ben Gurion University of the Negev, Israel

The field of conceptual change consists of multiple perspectives that combine many commonsense and theoretical ideas in kaleidoscope fashion, while a well-articulated theory is still missing. Sometimes it seems difficult to distinguish between different theories or ideas, while in actuality each brings different insights. To get a deeper understanding on the topic, it is time now, after three decades of research, to clarify the difference and similarities between the different theories, especially between those which might be confusing. In this paper, I discuss the differences and similarities of the intuitive rules theory and the p-prim theory, which, are wrongly treated by some researchers as nearly synonymous. After a brief description of the two theories, I compare them with respect to the following points: types of knowledge, number of knowledge elements, and the situations which the theories explain well. This discussion might help researchers to use the theories in a more accurate manner when explaining their research findings.

Coordinating diSessa's View of Conceptual Change and cK ϵ Model

Andrea Maffia, Doctoral School in Human Science, University of Modena and Reggio Emilia

In many of his works, Andrea diSessa advocates the necessity for more precise models of Conceptual Change. The model proposed by this author (diSessa, 1996) does not include general definitions of conception and concept, constructs which seem to be basic in a theory of Conceptual Change. Rigorous definitions of such constructs are given in the cK ϵ model by Balacheff and Gaudin (2002). A possibility of networking between the two theories is explored: a coordination is found defining diSessa's forms of knowledge as different conceptions of the same object according to cK ϵ definitions. This change of perspective can give some precise parameter to assess the switch from a knowledge form to another. According to strategies for networking by Bikner-Ahsbabs et al. (2010), this kind of coordination is possible because fragmentation of knowledge is a strong principle shared by these theories. Usage of both theories to interpret a single interview is proposed as a possible empirical validation for this proposal.

Explanations That Make Sense: What Makes Students Feel That One Explanation is Better Than Another?

*Shulamit Kapon, University of Haifa
Orit Parnafes, Ben Gurion University*

From a very young age, humans try to explain the phenomena they encounter for sense making and social purposes. Moreover, humans frequently evaluate various explanations of the same phenomenon, choosing the one that seems better to them and rejecting the one that seems

worse. We suggest a theoretical construct to account for the process of internal evaluation, which we metaphorically term the "internal metric for certainty in explanation". We start by arguing, based on the literature, that humans indeed possess such internal metric, and that this metric is highly contextually dependent. We then operationalize this elusive metaphorical term for the special case of explanations of phenomena in the physical world, by characterizing three dimensions that we view as highly active in self-evaluating explanations. We illustrate our claims through an analysis of an episode of a student's reasoning about what causes a plastic bottle to shrink when air is pumped out of it.

PAPER SESSION VC (ROOM C)

TEACHER EDUCATION

Chair: Francesca Morselli, University of Turin

Students' Naïve Ideas as a Source of Reflection in Mathematics Teacher Education

Maria Mellone, University of Naples Federico II, Naples, Italy

Arne Jakobsen, University of Stavanger, Norway

C. Miguel Ribeiro, São Paulo State University, UNESP, Rio Claro, Brazil

We present results from a study using tasks aimed at accessing, discussing and developing prospective teachers' knowledge when interpreting and giving sense to students' non-standard productions. The final aim of developing (prospective) teachers' knowledge is pursued by reflecting on their own knowledge in situations that are considered to strongly denote promotion in such knowledge and understanding. These tasks were worked into our lectures and were audio and video recorded. In that sense, we are interested to inquire into how teachers develop their awareness of the different possible ways of dealing with an aspect of mathematical content by discussing students' naïve ideas, and on how the impact of discussing different possible conceptions may lead to new understanding and knowledge. Here we will present some results of the study by discussing a fragment of these video-recorded discussions from a course in Italy, using an inquiry-in-practice perspective. This discussion leads us to argue that work grounded in discussing students' naive ideas/non-standard reasoning represents a core aspect of the field of mathematics teachers' education – in terms of all the elements involved (considering educators also as learners).

Concept Networks of Complex Scientific Concept: Pre-Service Physics Teachers' Conceptual Development in Case of Electric Field

Terhi Mäntylä, University of Helsinki

Good understanding of scientific concepts and how they can be acquired is at the core of science teachers' knowledge. However, understanding a scientific concept requires understanding a net of related concepts and through this net a scientific concept gets its meaning. Changes in this net affect the meaning and understanding of the concept under inspection. In this study, we examine the changes between pre-service physics teachers' initial and final concept networks of the introduction and development of the electric field concept. The electric field is examined from three different but related viewpoints called force, energy

and source grounding. The interest is both on the overall changes of the networks and on the more local changes within and between the conceptual groundings. In practice, the changes in nodes, links and their connectedness were analyzed. The results show that pre-service teachers' concept networks changed in a direction indicating conceptual development in pre-service teachers' understanding of the concept of electric field.

Cognitive Negotiations of Science, Culture, and Urbanity in a Multicultural Science Education (MSE) Graduate Course: A Quasi-Exploratory Case Study of the Geo- and Body-Politics of Knowing

Phillip Boda, Columbia University: Teachers College/City Polytechnic High School

This study utilized Chi's proposed three types of conceptual change as a theoretical framework to explore the negotiations graduate students encounter whilst enrolled in a semester-long 'Urban and Multicultural Science Education' course. Five self-selected graduate students participated in this study. The development of Larkin's conception statements through member-check validation served to consolidate the interview data sets and Chi's hierarchal categorization model was used to define ontological assignments of conception statements ($Kappa = .82$). Final analysis followed Mignolo's epistemic disobedience suggestion for more critical democratic thought toward generating de-colonial societies based on geo- and body-politics of knowledge. Initial findings suggest that participants' cognition around science, culture, and urbanity could benefit from explicit discussions of the difference between that which is enunciated and the enunciation process.

PLENARY LECTURE III (5:00 – 6:30 PM) (ROOM A)

Chair: Mariana Levin, Michigan State University

Verbal Language and Conceptual Change in Mathematics Education: Seeking a Comprehensive Framework

Paolo Boero, Department of Mathematics and School of Social Sciences, Genoa University

Examples concerning the transition from arithmetic to probabilistic thinking, from empirical to theoretical treatment of problems in elementary number theory, and from synthetic to analytic ways of treating geometry problems, show the relevance of verbal language and its specific functions for conceptual change in Mathematics, and also the great variety and complexity of conceptual changes in Mathematics. A conceptual change may be identified here through a change of the subject's relationship to a problem situation, which involves changes in the use of, and connections between, some concept-words to deal with it. Adapting Habermas' elaboration on rationality in discursive practices results in a comprehensive framework for conceptual change, interpreted as transition from some ways of solving problems (Teleological Rationality), of validating statements (Epistemic Rationality) and of communicating with others (Communicative Rationality), to others. Specific functions of verbal language are re-considered in the rationality perspective. Educational implications are outlined for classroom teaching (as concerns planning, managing and analyzing didactical situations aimed at conceptual change) and teacher education (in order to enable teachers to identify salient characters of conceptual change in terms of transition from one form of rationality to another, and specific functions of verbal language in it).

DAY FOUR
FRIDAY, AUGUST 29TH, 2014

SYMPOSIUM SESSION III (8:30 – 10:30 AM)

SYMPOSIUM IIIA (ROOM B)

**DEVELOPING THEORETICAL THINKING IN MATHEMATICS AS CONCEPTUAL CHANGE: THE
ROLE OF ARGUMENTATION**

Organizers: Francesca Morselli, Department of Philosophy and Education, University of Turin

Cristina Sabena, Department of Philosophy and Education, University of Turin

Discussant: Nadia Douek, ESPE, University of Nice, France

Chair: Francesca Morselli, University of Turin

The symposium is aimed at discussing the shift from empirical to theoretical thinking in mathematics, studied in terms of conceptual change. An overarching question refers to the role of argumentation in promoting such a change. Each author will present and discuss the theoretical tools s/he is using to frame his/her work and to carry out the analysis of the experimental data. The contributions are complementary in terms of mathematical content at issue, school level, and focus on the different dimensions of the teaching and learning process (teacher's role, students' processes).

Contributed Papers:

**Algebra as a Proving Tool: Promoting Conceptual Change by Means of Meta-level
Argumentation**

Francesca Morselli, Department of Philosophy and Education, University of Turin

**From Empirical to Theoretical Arguments: Conceptual Change in the Case of Strategic
Interaction Problems**

Cristina Sabena, Department of Philosophy and Education, University of Turin

**Argumentation and Use of Artefacts in the Shift to Theoretical Thinking: A Case Study in
Geometry at the Primary Level**

Samuele Antonini, Department of Mathematics, University of Pavia

Mirko Maracci, Department of Mathematics, University of Pavia

**Instructional Strategies and Conceptual Change: The Role of the Teacher in Promoting
Fruitful Argumentative Activities for an Effective Approach to Algebra as a Tool for
Thinking**

Annalisa Cusi, GREM University of Modena and Reggio Emilia

SYMPOSIUM IIIB (ROOM C)

PRE-SERVICE AND IN-SERVICE TEACHERS' PROFESSIONAL KNOWLEDGE: DIAGNOSIS, INTERVENTION, AND CHANGE

Organizer: Henrik Saalbach, Saarland University

Discussant: Wim Van Dooren (Center for Instructional Psychology and Technology, University of Leuven)

Chair: Phillip Boda, Columbia University: Teachers College/City Polytechnic High School

The relevance of teachers' competencies for research on conceptual change is twofold: First, teachers' competencies substantially influence students' learning. Teachers' knowledge, beliefs, and instructional strategies affect whether and how students' concepts are being formed and restructured. Second, teachers themselves often carry misconceptions about specific contents, the nature of learning, or effective instructions. Therefore, research aiming at defining, investigating and developing teachers' professional competencies, in general, and professional knowledge, in particular, is a promising path in order to enhance instruction and learning. Teachers' professional knowledge is commonly conceptualized by three core dimensions: content knowledge (CK), pedagogical content knowledge (PCK), and generic pedagogical knowledge. The papers of this symposium target different dimensions of teachers' professional knowledge and their change through professional teacher education and development. The first study examines the effect of an innovative research-based training on improving pre-service elementary school teachers' CK and PCK with respect to teaching rational numbers. The second paper reports about a study on the development of generic pedagogical knowledge of pre-service science and mathematics teachers. Here, the researchers examine the assumption that the coherence in teachers' knowledge is a function of explicit learning opportunities. The third study examines whether kindergarten teachers' construal of (science) learning as conceptual change is related to specific scaffolding activities, and whether a shift in their beliefs induced by a professional development program is reflected by a change in their scaffolding activities. The final paper of the symposium comprises a critically discussion of theoretical and methodological issues concerning research on epistemological beliefs of pre-service and in-service teachers. The authors emphasize the need for an assessment of epistemological beliefs based on a substantive psychological theory.

Contributed Papers:

Improving Teachers' Knowledge to Teach Rational Numbers: An Intervention Study in Three Teacher Training Institutes

Fien Depaepe & Patrick Van Roy, Center for Instructional Psychology and Technology, University of Leuven

Ilona Hawrijk, Thomas More, Teacher Training College, Mechelen

Ann Palmaerts, Groep T, Teacher Training College, Leuven

Nathalie Vermeersch, Vives, Teacher Training College, Brugge

Joke Torbeyns, & Lieven Verschaffel, Center for Instructional Psychology and Technology, University of Leuven

Preservice Teachers' Pedagogical Knowledge - From Knowledge-in-Pieces to Coherent Knowledge?

Thilo Kleickmann, Leibniz Institute for Science and Mathematics Education, Kiel, Germany

Relations Between Teacher's Beliefs About Learning as Conceptual Change and Their Scaffolding Strategies in Early Science Instruction

Ueli Studhalter, ETH Zurich

Henrik Saalbach, Saarland University

Miriam Leuchter, University of Münster

Annette Tettenborn, University of Teacher Education Lucerne

Critical Reflections on the Research of Epistemological Beliefs

Robin Stark, Saarland University

Eric Klopp, Saarland University

PLENARY PANEL (11:00 AM – 1:00 PM)

Chair: Giorgio Bolondi, University of Bologna

CONCEPTUAL CHANGE ACROSS DOMAINS

In this plenary panel, the participants have each been asked to prepare a 15-minute presentation in which they articulate their view on what is generic to conceptual change across domains and what is unique to each of their specific domains. The discussant will then present a 15-minute commentary to be followed by a 45-minute open discussion among the panelists, discussant and the audience.

Panelists:

Topic: Conceptual change in science

Micheline (Micki) Chi, Arizona State University, USA

Topic: Conceptual Change in mathematics

Erno Lehtinen, University of Turku, Finland

Topic: Conceptual change in the social sciences

Cecilia Lundholm, Stockholm University, Sweden

Topic: Conceptual change and controversial issues

Gale Sinatra, University of Southern California, USA

Discussant: *Bruce Sherin, Northwestern University*

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