Representations in teaching and learning Physics

There is increasing interest in the role of multiple, multi-modal representations in learning (Lemke, 2004; Ainsworth, 2006; Tytler et al., 2013) across all subjects. The practice of science, and learning science both increasingly involve images, simulations and models, and mathematical symbolic expressions. Problem solving in science involves the development of abilities to generate and coordinate representations (Kozma & Russell, 2005), and meta-representational competence is a key skill that students need to develop to learn science effectively (diSessa, 2004). Difficulties with conceptual change can be characterized as fundamentally representational in nature (Tytler & Prain, 2013)

Much of the research into multiple representations has investigated issues surrounding student interpretation of the representations / models that configure scientific knowledge – the need to understand the conventions underpinning these representations and how they are coordinated to interpret phenomena and develop explanations (Gilbert, 2005). Teachers need to sequence, and coordinate representational work (Ainsworth, 2006). There is a growing interest in the role of representations in inquiry, where teachers guide students to construct and coordinate representations to reason and generate explanations of phenomena in ways that mirror the practices of science (Lehrer & Schauble, 2006).

This symposium includes papers that range across a number of these perspectives: issues for students with representational work, principles of teaching with multiple representations, and teacher professional learning associated with a representation construction approach. Paper 1 explores the relation between theoretical models, mathematical representations and the real world using video based classroom observations and survey. Paper 2 examines difficulties students have in translating physics problems into mathematical form, concluding that the production of graphical representations is a useful intermediate step to generating algebraic representations. Paper 3 examines the ways in which two teachers coordinate and link sequences of representations in explanatory work in astronomy, generating a number of principles underpinning quality practice. Paper 4 examines the professional growth pathways of teachers as they plan and deliver a unit of work in astronomy that uses a representation construction approach.

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Paper 1: Relating Theoretical Models, Mathematical Representations and the Real World in upper-secondary Physics

Explanations of physical phenomena are organized through theories and theoretical models (Adúriz-Bravo, 2012). The theoretical models are developed through a cyclic and interactive process of theorizing, discussions, experiments and observations (Giere, 1997), see Figure 1.

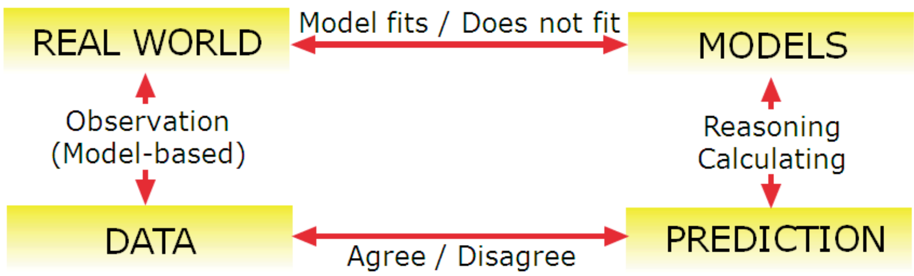

Figure 1. The real world and the world of theoretical models (adapted from Giere, 1997).

Also observations and experiments are by necessity embedded in theory and therefore ”Theory laden” (Hanson, 1958), thus there is a complicated relation between what we call a theoretical model with theoretical concepts and representations, and real world referents and real world phenomena.

Mathematical representations are often used in physics models of events in the real world. In physics studies students have been found to struggle with explanations and the solving of physics problems when they need to relate theoretical models to real world phenomena, especially while using mathematics, i.e. combining mathematical representations and operations with conceptual reasoning about physical phenomena – realising that equations can express a supreme meaning (Kuo et al., 2012; Uhden et al., 2012).

The purpose of this project is to further explore the role of mathematics for physics teaching and learning in upper-secondary school through investigating links made during physics lessons (lectures, problem solving and lab-work) between the constructs *The real world – Theoretical models – Mathematics.* The research questions are:

1. How are links between *The real world, Theoretical models and Mathematics* made during physics lessons?
2. How does the occurrence of links differ for different organisational forms (e.g. lectures, problem solving, lab-work)?

The study uses video-based classroom observations (lectures, problem-solving sessions and lab-work) and written surveys. A written instrument has been developed to complement the video recordings in giving students a possibility to express individual experiences after a lecture. One teacher and students in three classes in the science programme in an upper-secondary school have been studied during sequences of lectures, problem solving in groups, and lab-work. Three to four lessons (40-80 min) per class.

The data is analysed from a deductive perspective of finding the links shown in the "triangle of analysis" as depicted in Figure 2. The three sides of the triangle represent the different links.

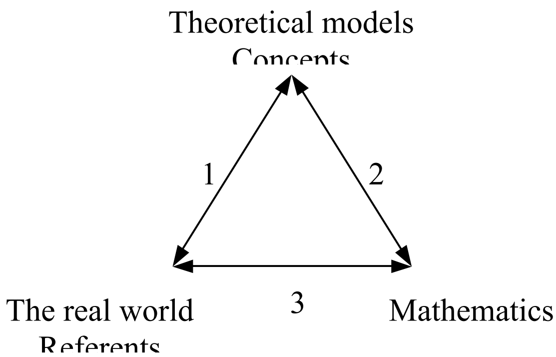

Figure 2. Theoretical models – The real world – Mathematics in physics teaching

The preliminary analysis indicates that models and concepts are introduced during lessons without links. This pattern is seldom broken. However, there were some situations where the described pattern was broken. The teacher commented on airbags and the length of hoods of cars in relation to the formula $W=F\cdot s$ thus helping students to link to a real world situation. Hence, there are links made by students and teacher between theories and the real world, but the bulk of the discussion in the classroom is concerning the relation 2 in Figure 2. That is on mathematic representations and manipulations of these. This result is in line with earlier research on problem solving. Surprisingly this result seems to hold true for all three investigated organisational forms, i.e. lectures, problem solving in groups and lab-work. A more detailed analysis will be presented at the conference.

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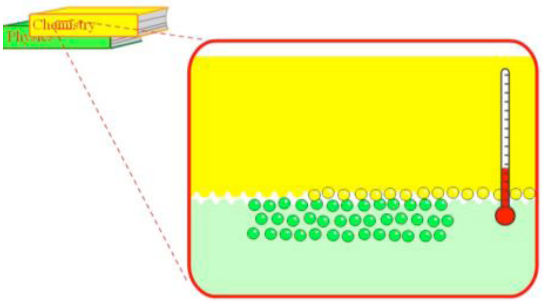
Paper 2: Some obstacles when interpreting information from visual representations

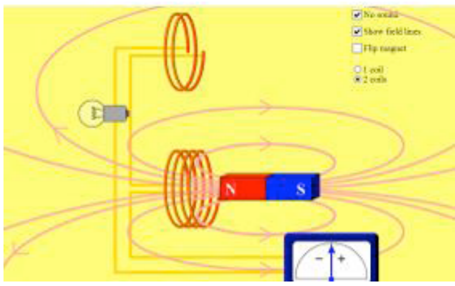
Using visual representations in our classes is, naturally, more and more frequent since the exploitation of images is the most common way to communicate at present. If we think the skills that should be boosted in our society, the ability to interpret visual representations will be one of the most relevant ones. That is, our youngster should be able to extract correctly the visual information that arrives to them.

In our presentation, we intend to show some obstacles that students have to overcome in order to have acquired such skill. We carried out a piece of research trying to analyse: *What are the obstacles that secondary school students have to overcome when faced with some simulations around the phenomena of Electromagnetic induction or around Increasing temperature by rubbing two surfaces?*

Half an hour interviews where done to 8 students 15-16 years faced in front of a simulation. The below images are a representation of them.



Simulation A



Simulation B

Students descriptions, when reading such "dynamic images" and interpreting its meaning, were analysed and conceptual requirements were carefully defined. (It is no matter of this presentation). What we would like to highlight in this symposium is that the extracted information doesn't correspond to the intended to be represented. We could realise that some mechanisms of reasoning seems to intervene on the distortion. Particularly, we will intend to describe two found mechanisms used by our students:

The elimination mechanism. Students "eliminate" parts of the images in the sense that they seem transparent to them. Some information conveyed for the simulation is not taken into account.

In some cases, this "removal" of information is unnoticed and comes from not properly perceiving the information that simulation is intended to convey. This is, for example, the case when students do not identify the irregular arrangement of particles in simulation A.

In other cases the participants perceive the visual elements but do not establish any relationship between them. For example, when students do not establish any relationship between particle vibration and temperature in this simulation A. That is, a central piece of the represented information is not captured for the participant making the simulation useless. When in this simulation, students do not catch the relation between rubbing the surfaces of the books and increasing the collisions of the particles (or increasing the temperature), the work around the simulation becomes negligible.

Another type of mechanism of reasoning seems to appear when student change the information offered for the images to another one more close to their minds. We called them **replacement mechanisms.** The information conveyed for the simulation is replaced for another one more accessible in their memory long term. According the heuristic of Tversky and Kahneman *(1974*), there is a tendency to attribute to each effect a cause that is more easily accessible. It may be some recent information that is retrieved effortlessly and is applied in different situations

We refer to situations in which participants replace the phenomenon presented in a simulation by another phenomenon recently studied in class. Students who have just studied electrical circuits interpret the magnetic field lines of simulation B as "the way of the electrons" and, participants of another school that had just been taught about "changes of state" interpret certain movement of particles in the simulation A as evaporation.

During the presentation on this symposium, details about such mechanisms appearing when secondary schools use simulations will be discussed.

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Paper 3: Coordinating representations in teaching astronomy: a cross-country comparison

Over the last two decades there has been increasing recognition of the central role played by multi-modal representational practices as part of the disciplinary literacies through which students reason and learn in science (Ainsworth, 2006; Kress et al., 2001; Tytler et al., 2013). While there is recognition of the need for teachers to use, interpret and coordinate representational work in science classrooms there has been little research into the specific ways in which such work occurs to support quality learning, or how effective representational practices might be situated within different pedagogical traditions. This paper draws on close video ethnographic analysis of astronomy lessons in two countries – Taiwan and Australia – as part of a wider cross-cultural comparative video study of competent elementary school teachers of science. The sequences were respectively 15 and 6 lessons long, each supported by significant digital and other representational resources. This representational work occurred within very different classroom organizational contexts, with disparate presumptions concerning the roles of teacher and students in constructing knowledge, different emphasis in assessment with Taiwan having a strong tradition of centralized competitive testing, and the greater focus on open group tasks in Australia. The Taiwanese teacher was a specialist science teacher while the Australian teacher was a science-enthusiastic generalist. The study aimed to identify whether within this contextual diversity there are transcendent principles governing the way representations and models are established and coordinated.

One lesson was chosen from each sequence, that included a series of models and representations, concerning moon phases (Taiwan), and the day/night cycle (Australia). The analysis shows the deliberate ways that these competent teachers 1) coordinate sequences of representations in a logical narrative, 2) transform representations across modes, and across dimensions (3D to 4D to 2D) in ways established for practice in science (Gooding, 2004), 3) explicitly focus students' attention on their salient features using gesture and metaphorical talk, 4) use deliberate strategies to link these partial representations in a sequence, and 5) monitor students' interpretation and use of representations. The Taiwanese teacher established coordination of earth and space perspectives as the key element of the modeling, through role-play, and metaphorical reference to 'earthlings' and 'astronauts' that persisted through and coordinated the successive representations. The Australian teacher made similar moves, but used open modeling tasks to challenge and monitor students' understandings. The study demonstrates the centrality of representational coordination as part of expert practice, and specific principles through which such coordination occurs, at the same time acknowledging variation due to cultural context. It also establishes important aspects of the nature and role of representations in learning science –that representations are partial, and that they do not 'speak for themselves' but need to be interpreted through negotiation of language and embodied experience. A framework is developed aimed at identifying and guiding effective representational work in the classroom to support quality learning.

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Teacher change in implementing a research developed representation construction pedagogy

This paper explores the issues in scaling up a research led pedagogical innovation which involved the development of a 'representation construction' approach to teaching and learning science.

The research program, Representations in Learning Science (RILS 2007-10), developed the representation construction approach working closely with a small number of teachers to plan and implement units of work. This approach involves challenging students to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science. The representation construction approach is based on sequences of representational challenges which involve students constructing representations to actively explore and make claims about phenomena. RILS has successfully demonstrated enhanced outcomes for students, in terms of sustained engagement with ideas, and quality learning, and for teachers' enhanced pedagogical knowledge, and understanding of how knowledge in science is developed and communicated (Tytler et al 2013).

Following RILS research the representation construction approach was translated into wider scale implementation within a current research program, Constructing Representations in Science Pedagogy (CRISP 2012-14), working with new teachers in a range of schools, investigating the issues and factors that determine the quality of uptake. This paper focuses on one of the CRISP schools which involved four Year 8 teachers who implemented the representatin-construction approach to the topic of astronomy. The research question: What are issues that confronted four Year 8 teachers in implementing a represention construction approach to teaching and learning astronomy?

Data was generated from teacher interviews, video capture of selected classrooms, field notes taken of researcher-teacher interactions, pre and post-testing of students and student work. The Interconnected Model of Teacher Growth (IMTPG) (Clarke & Hollingworth, 2002) was used to analyse the teachers' experience in planning and delivering the teaching sequence. There was a range of issues that confronted the teachers and conditions that proved significant for successful implementation for them included: preparedness of the teacher in terms of epistemological positioning and positioning as a learner; significant support for planning and modeling by the university expert; and a team ethos where teachers share ideas and plan jointly.

The IMTPG consists of four domains: the personal domain, the domain of practice, the domain of consequence, and the external domain. The model suggests that a change in one domain is translated into another domain through the mediating process of enactment and reflection. We found IMTPG to be flexible in identifying the experiences of the teachers in different situations and demonstrating the complexity and the multifaceted nature of teacher change. We found that the domain external to a teacher is highly complex, consisting in our case of university experts, curriculum resources, and also the community of teachers involved. Two major characteristics of the external domain are central to our current concerns that are a relative silence in the model. First, the shaping and coordination of the resources exemplifying the innovation is critical for successful implementation. An important challenge we face is how to characterize the central aspects of the approach, in a way that is understandable and attractive to teachers, provides a basis for successful classroom experimentation, and is consistent with its deeper theoretical underpinnings. Second, the importance of peer collaboration is apparent in our data, such that input and feedback from colleagues acts as a critical supplement to the input provided by the researchers. Thus, we recommend that the model can be fruitfully extended or further interpreted to clarify the different dimensions of the external domain in particular.

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