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Does PISA 2006 paint a relevant and valid picture of Danish Students Scientific Literacy?

Jens Dolin & Lars Krogh

OECD's *Programme for International Student Assessment* (the PISA project) has had a profound influence on educational policy in Denmark – as in many other countries. The present research project 'Validation of PISA science' was initiated in 2005 and designed to shed light on the relevance, alignment and validity for PISA Science to a Danish context. The validation is carried out through three independent but interrelated components, each targeted by a specific research question:

Q1: *To what degree is the PISA framework in accordance with the intentions for the Danish compulsory science education?*

Q2: *Is the PISA science test format aligned with assessment culture in Danish science education?*

Q3: *Does the PISA 2006 test-setup give a valid picture of Danish students' scientific literacy?*

In this presentation main emphasis is on Q3, and especially on how PISA's *test-setup* constructs communicative situations and ultimately influences performance results. The PISA test-format is of paper-and-pencil-type, non-dialogic and without performance-oriented components. In contrast both assessment and classroom-practice in school science in DK traditionally has been oral, dialogic and performance-oriented. Consequently, the rationale of this subproject has been to re-assess Danish students in PISA 2006-items under such more (school) authentic conditions, to see how this might influence the picture of their science performance.

120 students were re-tested two hours each. The students were videotaped, and each student's performance was compared with their PISA-score. In addition we analyzed students' knowledge from a broader socio-cultural perspective, including their use of scientific vocabulary, their ability to explain and to argue, as well as their use of artifacts – and discrepancies between the students' PISA scores and their argumentations. The results showed significant differences between the PISA-test results and the more socio-cultural re-test as well as serious limitations in the PISA test setup. The results will be discussed and put into perspective.

Background

Denmark has participated in OECD's *Programme for International Student Assessment (PISA)* since it started in year 2000. The Danish performances in science have not been too impressive, with Rasch-scores 481 and 475, significantly below the OECD average, in years 2000 and 2003 respectively and an average performance of 496 Rasch-points in 2006.

The low scores and relative rankings have induced dramatical changes in the Danish compulsory school system ('Folkeskolen'). Most significantly a new regime of benchmarking and national tests has been implemented in Folkeskolen, where the PISA-relevant age groups and subjects are heavily targeted.

The present research project 'Validation of PISA' was initiated in 2005 and designed to shed light on the political assertions of relevance, alignment and validity for PISA Science to a Danish context. Though it is performed within a Danish educational context, its methods and results will have relevance for a broader audience. The research can hopefully contribute to the ongoing debate on the usefulness of large scale international surveys in science education.

Rationale and research questions

The 'Validation of PISA'-project places PISA2006 science in a national context through three independent but interrelated components, each targeted by a specific research question:

The curricular relevance of PISA 2006 Science is investigated by comparing the PISA aims, as they are expressed in the PISA 2006 Assessment Framework (OECD 2006), with the goals for the Danish science education. So, our first research question is:

Q1: *To what degree is the PISA framework in accordance with the intentions for the Danish compulsory science education?*

The second research question addresses whether the PISA test format is reasonable related to the predominant assessment culture in the Danish science classrooms or not:

Q2: *Is the PISA science test format aligned with assessment culture in Danish science education?*

The answers of these two questions form the basis of the third and most central research question:

Q3: *Does the PISA 2006 test-setup give a valid picture of Danish Students' Scientific Literacy?*

In this presentation main emphasis is on Q3, and especially on how PISA's *test-setup* constructs communicative situations and ultimately influences performance results. The PISA test-format is of written/paper-and-pencil-type, non-dialogic and without performance-oriented components. In contrast both assessment and classroom-practice in school science in DK traditionally has been oral, dialogic and performance-oriented. Consequently, the rationale of this subproject has been to re-assess Danish students in PISA 2006-items under such more (school) authentic conditions, to see how this might influence the picture of their science performance.

There is some related research on mediation and the effects of re-constructing the communicative situations on students' performance. Most relevantly, Säljö et al (Schoultz *et al.*, 2001a) found that dialogic 'probing' (interview) of students' understanding of electric circuits dramatically improved the view of students' performances from paper-and-pencil, non-dialogic TIMSS-testing. Other studies have documented how assessment results are influenced by the use of artifacts (Schoultz *et al.*, 2001b), peer-interaction (Saner *et al.*, 1994) or performance-measures (Weng and Hoff, 1999).

Research design and methodology

The first research question, Q1, was examined through text analytical comparison of goal categories, content, contexts, priorities etc. The second research question, Q2, has been investigated through teacher interviews and a survey including a representative sample of science teachers (N=1159).

The third research question, Q3, which we will concentrate on here, has been pursued by re-assessing PISA 2006-students along the following lines:

Tasks for our re-assessment:

In good time ahead of the PISA 2006 test we had access to the PISA 2006-units and settled upon three tasks for our research (S465 *Climate Zones*, S478 '*Antibiotics'*, S447 *Sunscreens*). They were chosen, because they reasonably span the science subjects, the PISA contexts, and competencies and knowledge categories from the PISA-framework. Furthermore, all three units were relevant to the Danish Curriculum, One of the units (S447) had the additional advantage that it was *about* a lab experiment, and its paper-and-pencil-questions could easily be integrated into a performance-task. Semi-structured interview-manuals were elaborated for each unit. Additional units were picked as controls for test-retest-effects (see below).

The sample of students:

The Danish PISA-consortium helped us draw a stratified sub-sample of their PISA2006-population, 120students from 30 schools within the larger Copenhagen area. All of these were VAP-re-tested 2-8 weeks after their participation in PISA2006.

The re-test-design:

Each re-test-session lasted 2 hours and comprised of three components:

PISA-like-paper-and-pencil-test: A number of units to were tested in the original format to control for improved performance due to test-retest-effects

Dialogic assessments: Semi-structured interviews with individual students about units S465 and S478. Interviews were conducted by trained research assistants and involved the use of relevant artifacts. Each interview lasted ½ hour and was video-taped.

Performance-oriented assessment with peer-dialogue: The S447-unit was conducted hands-on in student-pairs interacting with a research assistant. Typically this part would take another ½ hour, and it was video-taped, too.

Data analysis

All video-tapes have been analyzed by at least two researchers, and with dual analytic focus:

1. Direct PISA-comparison: The Danish PISA-consortium helpfully delivered the original raw PISA-scores for our sub-sample. To obtain scores for comparison we had to quantify our much richer qualitative data, holding students multidimensional, dialogic, practical performances against the original PISA-scoring criteria. In this way rich information on students' capacities are 'dumbed down' onto the one-dimensional PISA-scale, where only pre-defined responses give credit. Scores were discussed, clarified and inter-rater-correlations secured. Finally, we compared our scores and the original PISA score for each item (using ANOVA-procedures), and total scores were compared using Rasch-analysis.

2. The PISA-transcending analysis: Here we have analyzed students' knowledge from a broader socio-cultural perspective, including their use of scientific vocabulary, their ability to explain and to argue, as well as their use of artifacts. Furthermore, we have tried to map PISA-transcending, but unit-relevant, knowledge that students might enter during interviews (e.g. additional knowledge from Danish Curricula). Finally, as a supplement to the PISA-comparison we have pinpointed instances where students would achieve right scores from PISA-criteria using wrong arguments or wrong scores despite being able of right arguments.

Results

The very short answers to Q1 and Q2 are: Firstly, PISA 2006 has relatively high curricular relevance for DK, i.e. its content and contexts overlap considerably with the Danish curriculum. But it is a distinctive feature that the Danish curriculum is less orientated towards (narrow) standards. Secondly, the PISA test format should not be unfamiliar for the Danish students. It is therefore not possible to explain (away) the low Danish score in science only with differences in content or in assessment culture.

As for Q3 the results are more ambiguous:

Our direct PISA-comparison shows that interviews generally *improve* students' performances when measured against the original PISA-criteria. PISA's paper-and-pencil format is not able to capture all aspects of knowledge that its scales credit.

At the same time, our PISA-transcending analysis opens a new window into students performance, and judged against almost all of these more profound socio-cultural criteria the picture of students' performances tend to be *worse* than painted by PISA 2006!

Conclusions and implications

Our research shows that however relevant the PISA Framework is to a Danish setting, and however familiar its test-format is to Danish Students one should caution the picture it paints of Danish students' scientific literacy. Specific choices of test-format and restricted scoring criteria shape the 'results' of PISA 2006.

Having revealed the limited view afforded by PISA's post-positivist test-procedures, we must warn against making major reforms in schooling on the basis of the PISA findings *alone*. It may miss the real strengths and problems, at the risk of throwing (educational) babies out with the bath water.

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Minding the Gap between policy and practice of inquiry based science teaching in seven European countries: Norway, Germany, Denmark, Spain, France, Hungary and the United Kingdom

Doris Jorde, Jens Dolin, Kersti Klette, Sibel Erduran & Ghislaine Gueudet

Paper 1: Inquiry-based science teaching- an overview of what we know and what we do

Recent concerns for recruitment to science and technology careers in Europe have forced educators and policy makers to take a critical look at the way science is taught in schools. In the last 10 year period several reports have been published, confirming the same results – that revisions are needed in the way we teach school science and in how we educate science teachers (EU, 2004; EU, 2007; OECD, 2008; Osborne and Dillon, 2008). In response to European concerns for science education, the **Mind the Gap** project was established to critically look at the role of Inquiry based science teaching (IBST) in policy documents, to consider how innovative practice in science teaching is related to ideas of IBST and finally to further develop an established model (SINUS) of teacher professional development for the dissemination of our ideas for improving the teaching of science based on IBST.

Inquiry is at the heart of the scientific method. It is what scientists do when they attempt to understand the natural world by asking questions about systems or objects, by collecting data, making predictions, testing out ideas and making conclusions. Though what scientist do is not the same as school science, a scientific way of thinking is an important component of understanding scientific processes and becoming a scientifically literate citizen. Placing inquiry at the heart of school science is what models of inquiry-based science teaching set out to do – by creating opportunities for students to engage in the creative exercise of asking questions and being curious about the world around them.

It may be argued that there is no one definition or unified concept for inquiry based learning methods in science education. Generally the concept refers to learning and instruction designs that engage students in active and authentic problem solving activities that pay attention to diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (Linn et al., 2004; Anderson, 2006).

Generally, inquiry-based science teaching may be characterized by activities that pay attention to engaging students in:

- authentic and problem based learning activities where there may not be a correct answer
- a certain amount of experimental procedures, experiments and "hands on" activities, including searching for information
- self regulated learning sequences where student autonomy is emphasized
- discursive argumentation and communication with peers ("talking science")

These four dimensions of inquiry-based science teaching define the field of IBST and are used as a framework for policy and curriculum analysis in the Mind the Gap project.

The Mind the Gap consortium is dedicated to minding many of the gaps found between theory and practice, between policy and practice and between teaching and learning as they are related to the use of inquiry based science teaching. IBST is recognized as a one of the major forces for realizing educational goals and curriculum efforts across European contexts as evidenced by national and local science framework documents. Yet despite this emphasis at the political and intended levels, IBST does not seem to be the dominating mode of science teaching at the secondary level in Europe.

Current video studies in several European countries (Norway, Germany, Switzerland, France) indicate that teachers at the secondary level make little use of the tremendous repertoire of ideas for teaching that may be indicated by an IBST influenced curriculum (Klette, 2009; Klette et al, 2007; Tiberghien & Buty, 2007; Seidel & Prenzel, 2006). Over the decades a vast research literature has reported on how curricula initiatives and reforms have little or minimum impact on practices at the classroom level. There is reason to ask for more systematic and evidence based answers to the many questions that can be raised about the place and role of inquiry-based science teaching as well as the tools available to support it. What does IBST mean? What are the central tools, artifacts and models for realizing IBST? Does IBST mean the same thing in varied contexts and cultures? Are teachers able to implement IBST teaching within current educational structures? What are the connections between IBST and scientific literacy? Does IBST allow for the incorporation of modern teaching tools, including ICT? Does IBST promote relevance in science lessons? To put it shortly: What are the merits of IBST as a teaching method in science education?

Paper 2: Policies and Framework for Inquiry Based Science Teaching (IBST) Across Europe

The first contribution explores the relationships between policy documents and inquiry based science teaching. An overview of policies and curriculum frameworks of IBST across participating countries (cultures, educational systems, subject areas, recruitment issues) and how IBST is framed within these school systems will be presented. Understanding the cultural contexts of IBST in policy documents is a necessary step in the process of spreading and implementing models of science teaching in countries other than where they originate.

In the first level of analysis we look at the question of HOW science education is organized in five of the participating countries, according to national curricula as the textual policy level. Since all countries have national curricula we used these texts as a baseline for comparison. Lower secondary level is the unit of analyses, covering the age of 12- 16 in most countries. All curriculum texts were analyzed according to three dimensions:

- Structural features regarding how science education is organized
- Structural features of the science curriculum text
- Substantial features of the science curriculum texts

Results

The analyzed countries operate with different models of how to organize science education at lower secondary level. While science education is treated as an integrated discipline at lower secondary level in Norway, science education in Germany is based on the sub disciplines of Physics, Biology and Chemistry from grade 1. France Spain and United Kingdom use a mixed model, keeping science education integrated up to a certain level (grade 6 or 7) and then specializing into the sub disciplines. Required teacher competence points to quite distinct models, with Norway at one side of the continuum, requiring no subject specification, while subject specification is a prerequisite for teaching science at lower secondary level in all other countries.

Structural features of the curriculum texts, such as legal status, accessibility and main subject areas in defining science education point to a great deal of similarities across the analyzed nationalities. All curricula texts have regulative status and all texts are available on the internet. For most countries a hard copy version is also available. There is consensus across the countries in how to define the main subject areas of science education. All curricula text pay attention (though with different labels) to the four following areas: Organism and health; Chemical and material behavior; Energy, electricity and radiations; and Environment, earth and universe. The role of technology in science is especially emphasized in Spain and Norway but not in the other three countries.

Substantial features of the texts point to both differences and similarities. The analyzed texts represent different models in whether learning areas are nationally prescribed or left to the local level to define and interpret. While learning areas are nationally defined in Germany (i.e. Länder); France, Norway, Spain and UK have a combination of nationally defined learning areas supported with room for local interpretation.

Whether learning goals in science education focus on content areas versus competences is another dimension of variation between the analyzed countries. Germany specifies learning goals in terms of content areas while Norway and UK link learning goals to competences. France and Spain have a mixture of both models.

All countries link inquiry based science teaching (IBST) to skills of argumentation and communication. All countries further link IBST to practical experiments and "hands-on" activities. Students' autonomy is emphasized in the UK curriculum text but not in the other countries. Problem based learning and exploratory learning appears in the curriculum texts in all analyzed countries but means rather different things in the different countries. While the Spanish text underscore "strategies for problem solving" as central to define problem based learning, the French text pays attention to "choice of problematic situations". In the UK texts, authentic learning and to "learn how science works" are emphasized. Linguistic and more elaborated in depth analyses in how the different curricula texts understand IBST will continue to be explored and refined as the Mind the Gap consortium continues.

Paper 3: Diversity of scientific literacy in Europe

The growing importance of scientific issues in our daily lives – on a both a global, a national, and a local level - demands an insight in science and a willingness to engage in the socio-scientific debate on an informed basis. The ability to do this is often captured by the concept of *scientific literacy*. At the same time traditional teaching is necessarily changing from a rather transmissive teaching style to a more interpretive, in order to make students able to use and communicate their knowledge in out of school settings, and to prepare them for lifelong learning and future citizenship. Inquiry based science teaching (IBST) is a central element in this process. By focusing on the students' own questions and their ability to answer them, IBST is an efficient way to obtain scientific literacy.

It is therefore important to collect and develop good practices of IBST for scientific literacy and citizenship within the EU countries. The science literacy/IBST project does this in three countries: Denmark, England, and Hungary. The research questions addressed in this part of the symposium are:

- How is scientific literacy conceptualized in the curriculum in Denmark, England, and Hungary, and how are these conceptions influenced by local cultures?
- How have good science teachers in these countries implemented scientific literacy in their science classes?

As a theoretical background we have analyzed international literature on scientific literacy, and based on Roberts (2007) we have divided the many different approaches into two visions:

Vision I: 'looking inward to science itself'
The products and processes of science itself
Literacy, through knowing, is within science but relates to matters other than science

Vision II: 'looking inward from situations to science'
Characterized by situations with a scientific component which students are likely to encounter as citizens

To have a type of benchmark for scientific literacy we have utilized the PISA Framework 2006 definition (OECD 2006). This definition and the matching text have been influential in the way countries integrate scientific literacy into the national curriculum.

The methodological challenge was to find a way of comparing how different curriculum texts conceptualize scientific literacy. Rather than just adding to the textual analyses of scientific literacy available from each country and cross-nationally, we have chosen to create maps in order to make analyses and comparisons more precise and informative. These maps have been produced in the PAJEC software based on complex network theory. As a special feature these maps reveals strings of defining elements (concepts, actions, contexts, levels, etc.) showing the relative importance of the connections between the elements. The maps thus make up a visual representation of often complex texts with an integrated quantitative approach.

Maps have been produced for central curriculum texts from Denmark, England, and Hungary (and other countries) and by a special overlay technique these maps have been compared to each other and to the PISA definition. These representations make it possible to separate characteristic features of the different countries' understanding of scientific literacy, and especially to analyze how the two visions are weighted different. The presentation will demonstrate and analyze a selection of these maps, and discuss the validity and the reliability of the method.

Paper 4: Enhancing Inquiry-based science teaching with online resources

Web-based resources for science teaching and lesson preparation are increasing in their use throughout Europe. These resources bring new ways of presenting science into the classroom creating challenges for teachers, students and the curriculum. In this third paper we look at how inquiry based science teaching may be enhanced through the use of web based resources, asking about which features found within web-based resources are in fact appropriate for IBST.

In the first phase of the work, a focus was made on analysis by inspection of web-based resources. We drew on research about technology and inquiry in science teaching (Kim et al. 2007, Linn et al. 2003, Linn, 2004), and about the design of web-based resources (Fischer & Ostwald 2005, Gueudet & Trouche 2008), from which a grid of criteria aiming to analyze the IBST-potential of such resources has been developed.

The following IBST categories for the creation of an evaluation grid were used:

- General criteria: ergonomy, possible student customization, media, legal aspects;
- Scientific criteria: authentic problems, robustness of the problems across different teaching contexts, epistemic value of the situations; IBST-scaffolding for students, for teachers (proposition of scenarios – of helps for the students);
- Collective dimensions: possible involvement of the users in the design process, possible development of communities of practice.

During the symposium, we will elaborate on the criteria for development of the grid and apply this for the analysis of extracts of two resources: VITEN[1], and Pegase[2]. Researchers in science education were involved in the design of both resources; they are nevertheless quite different in their aims and objectives.

VITEN (Jorde & Mork 2007) is designed in Norway (generalizing its English translation is a part of the Mind the Gap project); it is widely used in science classes by teachers and students. VITEN offers interactive content, dynamic representations, tries to develop argumentation by proposing material to implement debates in class etc.

Pegase is designed in France, for teachers and teacher trainers. It proposes presentations for teachers of the outcomes of several research projects in science education, about modeling, students' misconceptions etc. It also includes lesson plans with various materials, grounded in the research results.

[1] http://genetechnology.viten.no/
[2] http://www.pegase.inrp.fr

The application of our criteria to these resources provides evidence that each of these resources has qualities for IBST, but also possible improvements, in several directions could be made. Some of the interesting situations proposed can loose their IBST- potential if they are misused; enriching the teacher scaffolding is thus an important issue. Nevertheless, the usefulness of additional material for the teachers depends on its appropriation; giving too much details and advice can hinder the use of a resource. Developing possibilities of collective work for the teachers seems a promising means to improve scaffolding and foster appropriation at the same time. Beyond these examples, we will provide first elements of guidelines for the design of quality IBST online resources.

Paper 5: Promoting argumentation in science education: Mind the Gap Project Perspectives from England and Spain

In recent years, the teaching and learning argumentation i.e., the coordination of evidence and theory to support or refute an explanatory conclusion, model or prediction has emerged as a significant educational goal. The case made is that argumentation is a critically important discourse process in science (Toulmin, 1958), and that it should be taught and learned in the science classroom (Duschl & Osborne, 2002; Erduran, Simon & Osborne, 2004; Jimenez-Aleixandre, Bugallo-Rodríguez, & Duschl, 2000; Kelly & Takao, 2002; Zohar & Nemet, 2002). In this paper, results from the Mind the Gap Argumentation projects based in England (Osborne, Erduran & Simon, 2004b) and Spain will be presented. The overall objective of the paper is to contextualize the role of argumentation in science teaching, learning and teacher education. The projects have integrated available teacher resources developed in England and Spain for supporting argumentation in classrooms and professional development, and embedding these in inquiry based science teaching. Sequences of lessons have been trialed across languages and contexts.

An argumentation package for teachers is being developed and will include resources for teachers (e.g. lesson plans and pupil materials) as well as snapshots of video to show examples of how argumentation ideas may be implanted in science teaching. The work in England and Spain is aiming to: (a) Produce resources for supporting argumentation-based inquiry activities, in collaboration with secondary school teachers; (b) Develop guidelines and resources for professional development related to scaffolding argumentation-based inquiry activities; (c) Generate rubrics, informed by criteria and guidelines for assessment of resources and professional development programs aimed at supporting argumentation-based inquiry activities. The key outcomes of the projects are resources for students, teachers, teacher's trainers and policy makers for example; teaching sequences; guidelines for professional development program leaders; and assessment rubrics for quality performances for purposes of self-assessment and for policy makers.

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Investigating scientific literacy documents with linguistic network analysis

Jesper Bruun, Jens Dolin & Robert Evans

International discussions of scientific literacy (SL) are extensive and numerous sizeable documents on SL exist. Thus, comparing different conceptions of SL is methodologically challenging. We developed an analytical tool which couples the theory of complex networks with text analysis in order to obtain clear visual images of what is meant by SL expressed in written text. The raw text was first parsed into one statement sentences. Then, a linguistic type network was created with nodes being the words used in SL texts, and a link between two words established if they were adjacent to each other in the one statement sentences. Using the program Pajek, we drew a map of the text showing the number of times a concept appeared in the one statement sentences, and the strength of links between words. Different SL texts was analysed in this way. The network description allowed for different calculations on the network data. For example a minimal description length approach partitioned the network in to groups of words, which was then seen to represent different visions appearing in the discussion of SL. In short, the networks allow for quantitative analyses as well as a quick visual overview of SL documents.

Background

The growing importance of scientific issues in our daily lives – on global, national, and local levels - demands an insight into science and a willingness to engage in socio-scientific debates on an informed basis. The ability to do this is often captured by the concept of *scientific literacy* (SL). As the European Union seeks ways to assimilate and use its collective expertise on teaching for scientific literacy, comparing and understanding the various country perspectives is essential. The conceptualization of SL in different countries varies, since it can be influenced both by international definitions of SL, like that of PISA 2006 (OECD, 2006), and by local culture. International discussions of SL are extensive (Roberts, 2007), and each country has numerous sizeable documents on SL. Thus, comparing different conceptions of SL is a methodological challenge. Rather than just adding to the textual analyses of scientific literacy available from each country and cross-nationally, we have chosen to create maps in order to make analyses and comparisons more precise and useable through visual analysis. Here, we present the ideas and rationale of our approach, as well as the tool we have created through developmental research.

Rationale, theoretical framework and research questions

When you want to convey information in writing, you have different ways of emphasizing the importance of different parts of the information. If a particular concept is important, you may choose to use a word or a set of words describing it many times. Another way of emphasizing is to link the concept to many other concepts. In any of these two cases the concept will stand out in the text. A reader going through the document will encounter this concept many times or in a lot of different contexts.

In a given context, concepts might be described by a single word. An example of this type of concept may be *science,* when e.g. science education policy makers talk of it. Other concepts, such as *scientific literacy* are not as readily defined in the same way. In the afterword, Douglas R. Roberts (2007) writes: “The literature on SL cries out for clarity of expression and meaning, as we discuss issues in our professional capacity.” This lack of clarity makes it difficult to compare SL across national boundaries. Typically, documents on SL are very long reports, which few people actually read. With the analytical tool developed in this work, we seek to couple existing theory from other areas of science in order to obtain clear visual images of what is meant by SL. This leads to the first research question:

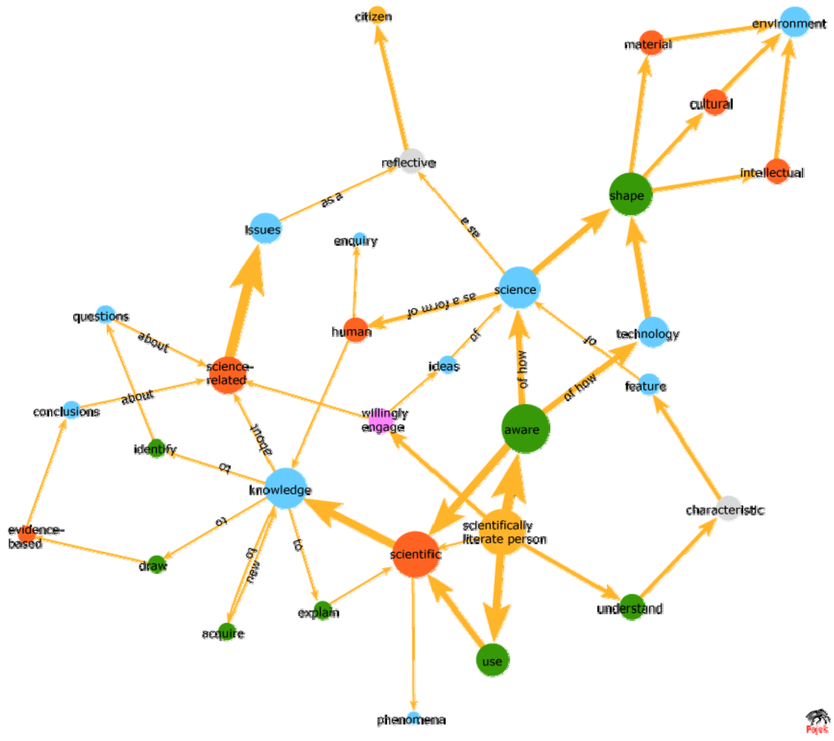
Q1: How do we make a visual representation of a text on SL, which allows for an effective and reliable overview of the text?

In physics, the area of complex networks is developing rapidly. A network consists of a set of nodes connected via a set of links (Newman, Barabási, & Watts, 2006). Recently, a number of authors

(Masucci & Rodgers, 2006) have investigated the network properties of the human language. Here, the nodes are words, and a directed link, *l_ij*, from *node i* to *node j* exists, if *node j* directly follows *node i*. If more than one link in a given direction exists between the two nodes, the weight of the link is increased proportionately. Coupling these findings with the research area of SL generates the next research question:
Q2: How can we use the tools of complex network theory to quantitatively and reliably measure the relative importance of words used to convey meaning in SL-texts?
Given a complex network, it is possible to do various analyses on the data (Newman, Barabási, & Watts, 2006). One method of particular interest is to partition the network into modules by minimizing the description length of a random surfer on the network (the MDL approach) (Rosvall & Bergstrom, 2008). In the context of text analysis, this gives us sentence bits, and it leads to the last research question.
Q3: Is it possible reliably to obtain sentence bits which are meaningful and what do these bits tell us about a given documents conception of SL?

Methodology

Our tool acts on the SL text in stages. The raw text is first parsed to a state, in which all sentences in the text are transformed so they contain only one statement. If some word is connected to other words in a list form, the sentence is split up (Bruun, 2009). The sentence:
"Students enjoy, respect, and appreciate science" becomes three sentences: 1. "Students enjoy science". 2. "Students respect science". 3. "Students appreciate science". We then label the different words with one of seven different categories: actor, action, concept, context, attitude, level/type, and structural words. Broadly speaking an *actor acts* (with some *attitude*) on a *concept* in a *context*. The level/type could relate to e. g. the degree of action or type of concept. The categories are loosely defined and serve as graphical indicators on the final visualization. All but structural words become types of nodes in a linguistic network. The structural words are used for labeling links between nodes. We then use Pajek (de Nooy, Mrvar, & Batagelj, 2005) to plot a graph of the network. Further, we use the MDL approach to find sentence bits. In the MDL, a random walker traverses the network. When going from one node to an adjacent node, the walker is allowed to follow the arrows alone. If more than one arrow leaves a node the walker chooses one of the arrows with a probability proportional to the thickness (strength) of the arrows. A random walker may easily get stuck, so the MDL algorithm gives the walker a probability for jumping to any node in the network at each step of the walk. This jumping random walker is called a random surfer (Rosvall & Bergstrom, 2008). After a sufficient amount of surfing each node has been visited with a certain frequency. It is possible to describe the path of a surfer with a code, and by grouping nodes into modules in which the surfer spends a lot of time, the MDL algorithm minimizes the description length. In the context of reading a text, the random



surfer can be interpreted as a person skimming through the text. We have used the tool on texts from three different countries to allow for comparison.

Data analysis

The figure shows one possible map of the PISA definition of SL following this approach. It was created using the computer program Pajek (de Nooy, Mrvar, & Batagelj, 2005). Initially, the nodes had the same color and size. Analyzing a number of texts, we built up a vocabulary of words used in texts on SL. This vocabulary was constantly updated and when we encountered a new word, we labeled it with one of the seven categories. A word thus belongs to the same category, even if it appears on different maps. Each node has a number of connections going in and out. For each node we noted both in connections, out connections, and the sum of in and out connections. In the analysis, we plotted nodes with their sizes proportional to the sum of in and out connections. This allowed us to compare the same node (word) in different maps (contexts). Also, we used the differences in and out connections to find end nodes (words at the end of sentences) and to check for errors. Comparing the size of a word, groups of words, or links between words in different maps, allowed for a structural analysis of the texts, part of which came from the MDL data.
The MDL data was modules of nodes. Each module then became a node in a new network. Each module has a size proportional to the time the surfer spends visiting nodes in the module and two modules are connected when the surfer goes from one module to another. In our analysis of the MDL data, we have named the modules according to the nodes in them, and our full analysis will be presented in the final report.

Results

To answer Q1 and Q2 we developed the tool described above and used it on texts from different cultures. In the complete article, we report on differences between these texts. We have tentatively answered Q3 by using the MDL method on the PISA 2006 network, and we have named each module. The development of this tool was an iterative process. This means that awareness of constraints is also a part of the results. One major constraint was that we could not neglect the context in which the documents appeared. For example, comparing national policy documents with curriculum documents within countries is fruitful. But for a cross country comparison, we compared documents with similar status.

Perspectives

The tool has been developed for analyzing SL documents. However, we believe that it has general application value to other complexly defined concepts as well. Also, different choices made during the parsing procedure may serve as a way of visualizing different interpretations of the same document. The tool will be implemented as part of a larger, interactive tool for teacher professional development, so users can quickly create an image of relevant policy documents. Finally, this quantification opens up possibilities for other types of network analyses, for example the accessibility and predictability of the network.

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Problem types in Science Education

Frederik V. Christiansen, Lars Ulriksen, Michael May, Martin Niss & Camilla Ø. Rump

In this round table discussion, we will present a model that distinguishes four different types of problems that students in university science and engineering education work with. The model is based on the analysis of problems in terms of the openness of the problem's formulation and solution space, respectively. The four categories are termed closed problems, vague problems, design problems and open problems. Dominant problem based teaching methods in science and engineering (PBL, project work, CDIO) are related to the categories, and four researchers, each with special insight into one of the four categories of problems, will provide examples and reflect upon the nature of the specific type of problems. The discussion will address the students' potentials for learning in relation to the various types of problems, the model's implications for curriculum design in tertiary education, and the adequacy of the model for describing the problems encountered in education and scientific practice.

Problem statement and definition

In the Structure of Scientific Revolutions, Kuhn (1970) described the scientific practice of normal science as a kind of "puzzle-solving" activity, where scientists adhering to a paradigm worked on problems given within the framework of the paradigm. Thus, the problems dealt with are confined by the paradigm, and have a unique solution determined by it. Kuhn described these problems as 'that special category of problems that can serve to test ingenuity or skill in solution', and added: 'Though intrinsic value is no criterion for a puzzle, the assured existence of a solution is.' (Kuhn, 1970, p. 36). Thus, Kuhn – while acknowledging the existence of other types of problems – delimited scientific problems to a certain class of well-defined problems, each with a unique and 'group-licensed' solution. While it is clear that Kuhn's description of normal scientific activity was somewhat caricatured, there can be no doubt that this type of problems actually play a crucial role in science education, particularly in such fields as physics. However, it is also clear that other types of problems are increasingly finding their way into science education, and with good reason. For instance, Bucciarelli argues that 'puzzle-solving' cannot adequately describe the problem solving practice of designing engineers, or at least only if the puzzle pieces can be constructed as they go along, and the image of the whole is not predetermined. Consequently, puzzle problems do not suffice in engineering education (Bucciarelli, 2003). Likewise, Donald Schön (1983) critizised the way that universities had increasingly removed themselves from practice, and rhetorically asked 'Shall the practitioner stay on the hard, high ground where he can practice rigorously [..] but where he is constrained to deal with problems of relatively little social importance? Or shall he descend to the swamp where he can engage in the most important and challenging problems if he is willing to forsake technical rigor' (Schön, 1983, p. 42). In the past 30 years, there has been a movement in science education towards increasing focus on 'non-puzzle-problems'. Entire teaching formats have been developed with this objective, for instance in such methodologies as PBL, CDIO and project based education. The shift towards outcome oriented education in recent years has fuelled this process. In this paper we will distinguish between four different types of problems encountered in science education and discuss the merits and limitations of each of the types.

Making sense of problems: A matrix of problem types (presented by Author1)

In artificial intelligence and expertise research, the problems that do not readily afford an answer have been termed ill-structured (e.g. Newell, 1969, Voss & Post, 1988). However, the term ill-structured problem, which is also commonly encountered in educational studies, is not very precise because it is not clear whether it is the definition or the solutions (or both) that are ill-structured. From a pragmatic and analytical perspective, a problem consists of a formulation or definition, and a solution space. Based on this assumption we will distinguish between four types of problems, as described in Figure 1.

A typology of problems based on their definition and their solution space	Problem formulation: Closed	Problem formulation: Open
Problem solution: Closed	**P_{11}** Closed problems	**P_{21}** Vague Problems
Problem solution: Open	**P_{12}** Design problems	**P_{22}** Open problems

Figure 1. *The problem matrix describing four types of problems in terms of their formulation and solution. The indices on the P's refer to formulation, solution respectively (1=open, 2=closed).*

Kuhn's puzzles are types P_{11} and P_{21}. The problems of type P_{11} are well-defined in their formulation, and have a "predetermined" pattern as their solution. Such problems are found in abundance in science textbooks. P_{21} could perhaps be termed riddles, rather than puzzles. Since they are open with respect to their formulation, an important task consists in rephrasing or reducing the problem in such a way that it may be connected to the predetermined pattern, for instance by making certain idealizations. For instance, many PBL cases in medicine are of this kind: Students get a vaguely formulated description of a patient with certain patient history and symptoms, and are required to find out which parts of the description are essential in order to reach a correct diagnosis or differential diagnosis. Design problems (P_{12}) are problems which are well-defined in their formulation, but ill-defined in their solution space. An example of a type P_{12} problem could be "Make a dish fit for an emperor using only a chicken, onions, mushrooms, tomatoes and wine" (example from Reitman, 1965). In new formats for organizing engineering curriculum, such as CDIO, such problems play an important role. Finally, problems of type P_{22} are problems where both solutions and initial formulations are to be specified. Such problems are dealt with in for instance project based education, as found e.g. in several Danish universities.

P_{11} (presented by Author2): Problems which are well-defined or closed in their formulation as well as in their solution sometimes become more and more standardized over time in a way that may eventually invite students to apply surface learning strategies, rather than deep learning strategies. Examples of this are the so-called end-of-chapter-textbook-problems used in undergraduate physics and engineering. Here, a successful strategy may be to search for the right formula and then, without reflecting, plug in the given parameters; a strategy which has little to do with actually learning physics or engineering. However, if standardization is dealt with, such problems may provide students with crucial technical skills. Moreover, P_{11} have the advantage that they are very useful for quantitative tests of students' learning, and tests can be used formatively to great advantage for both students and teachers. In certain scientific fields, being able solving certain P_{11} type problems is a core competence, particularly because other problem types are often reduced to problems of type $P_{11.}$

P_{21} (presented by Author3): We will present some non-traditional physics problems of type P_{21} used in a university physics course. The problems are real-world problems stated in everyday language that are designed to have preferred solutions based on central physical ideas. An example is: *On arriving to a cold house, the electrical heating system is switched on. How does the temperature in the house change as a function of time? Justify your answer*. These problems focus on other problem solving skills than more traditional physics problems of type P_{11}, in particular the ability to reduce the problem from the open formulation to the predetermined pattern and to evaluate whether an obtained solution makes sense physically.

P_{12} (presented by Author4): Design activities in engineering are usually constrained in their formulation by multiple requirements imposed on different levels of organization (functionality, users, environmental issues, cost etc.), whereas a design space of potential solutions can be seen as open to creative inventions as well as new configurations of old solutions (‘tinkering’). The design space as such is however not completely ‘ill-defined’, since it is constrained categorically by its dimensions, e.g. by choices of materials, media, forms of interaction etc. and by the resulting functionality and usability of the products. Some design activities in fact turn out to be vague problems (type P_{21}), e.g. when requirements are not fully specified or when new consumer products are “suggested” to the market without any prior need. Defining a set of possible design solutions based on a specification of requirements (P_{12}) play an import role in modern engineering education. Cognitively it requires students to engage in hypothetical thinking by setting up claims about the functionality and usability of future products based on models, prototypes, theoretical knowledge and experience.

P_{22} (presented by Author5): Problems of type P_{22} provide students with unique potentials for learning how to transform a problem which is a 'complex mess' (Schön, 1983) into a problem, which may be analysed and answered. In virtue of being actual theoretical or practical problems (that is, not problems designed with a specific closed solution in view, as in P_{21} and P_{11}), the students are challenged on their ability to work professionally with complex phenomena, and provide answers that were not given in advance, similar to Schön’s distinction between problem solving and problem setting. The downside to working with such problems is that it is very demanding of the students, in terms of their motivation and independence. Moreover, the supervision of students has to find just the right balance between guidance and control. This is particularly true with respect to the choice of the problem, which should no be so complicated that it is beyond the students to approach it by themselves, but at the same time it has to be relevant for the study programme as such. A different challenge is that the institutional framing of the project work means, that the students sometimes reduce the problems to classical ‘what does theories x and y say about phenomenon z’, thereby changing the nature of the problem to something like P_{21}.

General discussion

There can be little doubt, that students in much science and engineering education have spent vast amounts of time on solving P_{11} problems, and far less time working with other types of problems. In one way Kuhn is right that such problems lie at the heart of scientific practice, because other types of problems are often reduced to type P_{11} in the course of the problem solving process. However, because of their artificiality compared to the problems encountered in professional practice they are not in themselves sufficient to provide students with relevant opportunities to develop the needed qualifications. Solving problems of type P_{11} is necessary, but not sufficient. But what types of problems should be worked with in different types of science based education? The choice of problems depends to a large extent on the type of study. It makes perfect sense, that PBL problems of type P_{21} are frequently used in medical education, because the general practitioner has to face patients who pose such “vaguely defined problems”. Architects, designers and engineers often have to develop solutions to problems which are well defined, but which have many possible solutions. Therefore, problems of type P_{21} are increasingly used in such study programmes. Letting students work with the problems of type P_{22} may provide them with the ability to delimit and identify problems in complex settings, and this is generally considered a valuable competency in many different scientific fields.

There are certainly limits as to how long one should stretch a simple model like the one suggested here, particularly the co-evolution of formulation and solution space is ignored. Still, the matrix of problem types does capture some central differences between types of problems, and may contribute to greater precision in the discussion of the function of problem based science education.

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Graph comprehension in science and mathematics education: Objects and categories

Frederik V. Christiansen & Michael May

The first part of the paper presents a taxonomy of representational forms inspired by Peircian semiotics and Duval's description of learning in mathematics. The typology highlights the possibility that students may conceive of e.g. a graph as another type of representational form. Specifically, the typological mistake of considering graphs as images is discussed related to litterature, and two examples from engineering education are given. The educational implications for science and engineering are discussed, with emphasis on the need for students to work explicitly with conversions between different types of registers. In the second part of the paper, we consider how diagrams in science are often composites of iconic and indexical elements, and how this fact may lead to confusion for students. In the discussion the utility of the Peircian semiotic framework for educational studies of representational forms in science is discussed, and how the objects of mathematics and science relate to their semiotic representations.

Problem definition and context

The problems of graph comprehension are reported in many studies of science learning in high school as well as in higher education learning. An early example is the studies of students' understanding of kinematics and problems of associating graphs with their physical interpretation (e.g. McDermott et al, 1987). A recent review of the literature on graph comprehension (Shah & Hoeffner, 2002) supports these early findings and lists four implications for the educational support of graph comprehension: (1) graph literacy skills should be taught explicitly (and in the context of different scientific domains), (2) activities where students have to translate between different types of representations will improve their understanding, (3) students need to pay attention to and be trained in the relation between graphs and the models they express, and (4) students should be encouraged to make graph reading a meta-cognitive activity, i.e. to pay attention to and reflect critically on the interpretation of graphs. In a recent article by Duval (2006) a more general semiotic perspective of representational forms in learning mathematics is presented, which adds perspectives to the results found in the graph comprehension literature. Duval approaches the subject by considering the epistemological question of mathematical objects, and the role played by semiotic representations in cognition of these objects. In the current article we will sketch a theoretical semiotic approach to representational forms, including graph comprehension. We will present a taxonomy of representational forms, and discuss the distinction between modes of representation in science and in mathematics.

A taxonomy of representational forms

According to Duval (2006), a semiotic *register* (i.e. representational form) is characterized by two central factors. Firstly, they afford the user with the ability to perform certain *treatments* of objects within in the register. For instance, in a geometric representation, two points may be connected by a line. Similarly, in the algebraic register, a functional value may *be computed* by following the procedure described in the function. Secondly, a semiotic register affords of *conversion* to a different registers, for instance conversions between the geometrical register and natural language. Duval argues that mathematical objects are unlike the objects in the sciences in that the objects of mathematics are only accessible through semiotic representational forms. While it is clearly correct that mathematical objects are only accessible through representations, we disagree with Duval that the objects of science should somehow be non-semiotic. The difference is rather that mathematics as a science deals only with a special types of signs, described in Peircian semiotics as *hypoicons*. Such signs are symbolic but underscore the *similarity* between sign and object. This similarity may however be conceived in two ways – similarity by virtue of a qualitative resemblance and similarity in relational structures. The former type of signs are termed *images*, the latter are termed *diagrams*.

Based on the Peircian framework, the article will suggest the following more extensive taxonomy of representational forms (see also Author1, 2006) [extended description of background for taxonomy in full paper.].

	Diagrammatic Registers (allowing treatment and conversion)				
Image	Map	Graph	Diagram	Language	Symbol
Concrete-iconic		Abstract-iconic		Symbolic	

Figure 1. *A taxonomy of representational forms. The 'concrete-iconic', 'abstract-iconic' and 'symbolic' division is from (Purchase & Naumann, 2001).*

Examples of typological errors from engineering education

[Only one example in synopsis] One of the typical problems found in graph comprehension, even in higher education, is the interpretation of graphs as 'concrete iconic' objects, i.e. images rather than relational structures. It is known that many students, also in higher education, tend to focus on images or pictorial characteristics when making judgments, rather than on similarities in structural relations between properties (Gentner, 1989; McDermott et al., 1987). An example found in students of chemical engineering at the [Name of university omitted] is described in figure 2.b. (See also Author1, 1997).

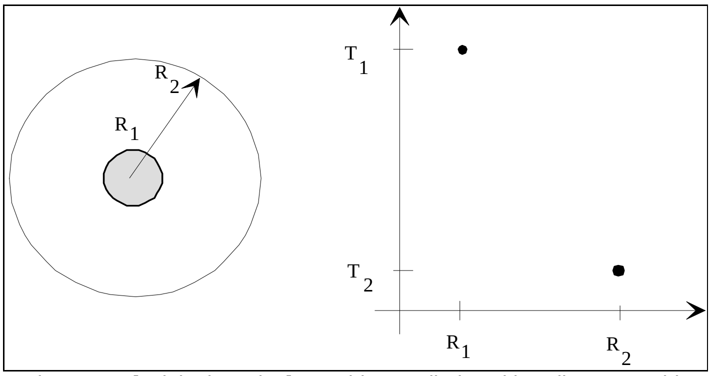

Figure 2.a: [Original caption] Consider a cylinder with radius R2. Inside the cylinder is a kernel with radius R1 and which has been heated to the temperature T1. At the surface (with radius r = R2) the temperature is held constant at T2 where T2 < T1. Show in the diagram a qualitative sketch of the graph T(r) for values between R1 and R2 (i.e. you do not have to compute any values for points on the curve).

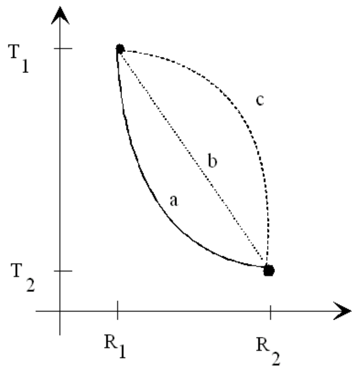

Figure 2.b: Answers to problems in fig. 2.a. The correct answer is (a). Answers (b) and (c) are student responses.

Figure 2. *Figure 2.a shows a conceptual test given to students in a course in chemical engineering at [Name of University omitted]. Figure 2b shows correct answer, and student responses.*

Three types of answers were given by students (fig. 2.b): the correct answer (a), the linear answer (b), which is motivated by the original context where students learned about the law, and (c) where student have remembered the shape of the image, but without any physical understanding of the model represented by the graph. The students who answered (c) to the test in fig. 2.b could not give any physical interpretation to the graph since it was remembered as a mere image of a textbook (or lecture) presentation. This exemplifies a 'typological error' within the representational forms used in reasoning by the students: treating a graph as if it was an image (or effectively reducing it to a mental image).

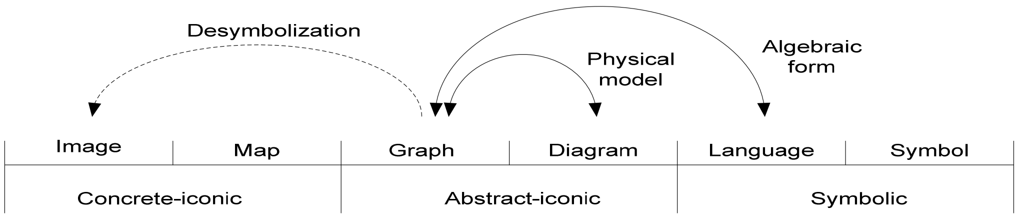

Figure 3. *Conceptual diagram to indicate the 'desymbolization' of graphs reduced to concrete-iconic images by some students and the didactic importance of training students actively in converting between different registers, for instance in conversions to the diagrammatic understanding of the physical model, or natural language.*

Graphs in science: Confusing phenomenon with model object

In graphs and diagrams describing empirical findings, a different type of sign is present: The index. Unlike hypoicons, these signs refer to their objects by virtue of a direct, often causal, connection to their objects – not in virtue of the similarity between sign and object. Figure 4 may serve as an example. The measurement points are indexical and refer to a physical phenomenon (measurements). However, the line is hypoiconic - it describes a potential relation between the two variables and a structural similarity to the phenomenon. Thus, the object represented by the line is not a physical phenomenon, but rather an ideal mathematical object. We shall term such scientific entities *model objects* to distinguish them from the phenomenon. Scientific diagrams, unlike mathematical diagrams, often contain both model objects and (indexical representations of) phenomena. However, the distinction between iconic and indexical elements in graphs is often blurred. This important semiotic distinction will be illustrated with several examples in the full paper.

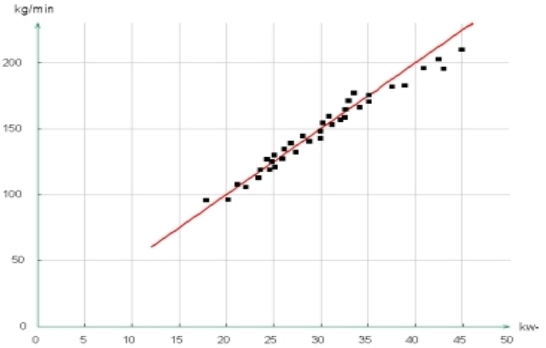

Figure 4. *Figure showing net power used for driving spinning wheels which draw fibres for mineral wool as a function of the amount of melted stone pr. time. The dots represent measurement points, and the line represents a linear regression. (Graph from Author2, 2007a).*

The model object in Fig. 4 presents a hypothesis about the phenomenon, and clearly other model objects could be envisioned (for instance nonlinear ones). In a series of interviews with students and expert engineers about problems experienced in a mineral wool production plant, it was found that several students had difficulties with graphs like this. One student mistook the approximation (model object) for the actual relationship (phenomenon) between the variables, and considered the deviations from the graph as inaccuracies in measurement. Thus, this student confused the phenomenon and model object presented in the graph. Since such graphs are abundant in many fields of science (but not in mathematics), the difference between phenomena and model objects in scientific diagrams should be considered.

Discussion/conclusion

Adopting a semiotic approach to the understanding of representational forms in science, as the one suggested by the above, carries the opportunity to bring increased rigor to our understanding of students' problems in understanding graphs and diagrams, for instance by enabling the identification of typological misconceptions in diagram comprehension, and confusion of objects in scientific diagrams. Duval's discussion of mathematical objects and the semiotic representations of these may be generalized to model objects and their representations in science.

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Validating the use of teaching contexts as contributors to the self-efficacy of science teachers across cultures

Robert Evans

International interest in the usefulness of self-efficacy and its association with science teaching has grown over the past 30 years. More recently, the importance teaching environment has on self-efficacy has begun to be studied, first in the United States and then elsewhere. However, while assessments of personal capability beliefs such as self-efficacy have long been accepted as valid in many cultures, largely variable local science teaching environments have yet to be established as having significant associations with self-efficacy. This paper begins such a validation process by looking at some recent research in Australia, India, Taiwan and northern Europe

Background, Framework and Purpose

In his original work, Bandura (1977) showed that, based on life experiences, people have specific expectancies about their action-outcome contingencies. They act not only because they believe their actions will result in specific outcomes but also because they believe in their own ability to perform those actions.

In 1997, Bandura went a step further and detailed some mechanisms by which the self-efficacy of teachers is maintained, raised or diminished. Significantly, he strengthened the link between self-efficacy and the extent to which it is influenced by the context of the situations in which teaching is performed (Bandura, A. 1997).

Another important contribution to understanding motivation and control beliefs was made by Ford (1992), who proposed a comprehensive 'person-in-context' model to describe the motivational processes associated with individual achievement and competence. He postulated that '…a motivated, skillful, and biologically capable person interacting with a responsive environment…' is essential for personal achievement and that if any of these parts are diminished or absent, competence will be compromised (Ford, 1992, p. 70). Ford characterized motivation as: "Motivation = Goals x Emotions x Personal Agency Beliefs" (Ford, 1992, p. 78). Goals can be either personal or institutional or a combination of both, but they are essential for motivation. Emotions are tied to goals in that they have a positive effect on motivation by giving the individual the energy to act when these goals are likely to be met by given actions (Ford, 1992). Intimately associated with goals and emotions are personal agency beliefs, which are composed of both capability and context beliefs. These personal beliefs about an individual's assessment of his/her ability to perform a given function (capability) and the helpfulness of the environment in that performance (context) are essential precursors to action. Ford (1992) says that each of these three motivational components is necessary for someone to be successful at a given task.

Both Ford (1992) and Bandura (1997) suggest that an understanding of the role that motivation plays in the performance of teachers requires knowledge of their goals, emotions and personal agency beliefs (capability and context beliefs). Instruments to assess personal agency beliefs and teaching context for teachers of science have been developed. Since Bandura's (1997) self-efficacy is a form of personal capability, the subscale of the Science Teaching Efficacy Beliefs (STEBI) instrument designed to assess self-efficacy (Enochs & Riggs, 1990) is appropriate for assessing the capability part of personal beliefs in the Ford (1992) model. The Context Beliefs about Science Teaching (CBATS) instrument developed by Lumpe, et al (2000) has been specifically designed to measure the context beliefs part of Ford's personal agency beliefs (Ford, 1992).

Rationale

International interest in the usefulness of self-efficacy and its association with science teaching has grown over the past 30 years. More recently, the importance teaching environment has on self-efficacy has begun to be studied, first in the United States and then elsewhere. However, while assessments of personal capability beliefs such as self-efficacy have long been accepted as valid in many cultures, largely variable local science teaching environments have yet to be established as having significant associations with self-efficacy. This paper begins such a validation process by looking at some recent research in Australia, India, Taiwan and northern Europe

Methods

This contribution reviews recent research studies which when taken together, contribute to the beginning of an international validation of the association of teaching contexts and self-efficacy. Adding to the American look at self-efficacy beliefs and context (Enochs & Riggs, 1990; Lumpe, et al 2000), research in Australia, Asia, and northern Europe have assessed the personal capability beliefs of teachers as well as the context of their teaching as a way to gauge the effectiveness of pre-service (mainly) and in-service teacher education programs. The results of the more extensive northern European study are detailed and examined as a potential model for validation in other cultures.

Results

In Australia, Appleton, K. and Kindt, I. (2002) found for new elementary teachers of science, a strong association between self-image (analogous to self-efficacy in their study) and teaching contexts such as limited resources, collegial mentoring, time and administrative support. They found that for new teachers, the availability of resources such as equipment and teaching ideas affected teacher's perceptions of themselves.

An Indian study of elementary and middle school science teachers found significant positive predictors of self-efficacy to include the contextual elements of time spent teaching science and a written curriculum, while years of teaching experience was a negative predictor of personal capability beliefs (Desouza, J.M.S., Boone, W.J. & Yilmaz, O., 2004). The authors were mindful of the differences between Western cultures and those of India when using a translation of a version of the STEBI instrument to assess self-efficacy and a locally relevant assessment of demographic variables with many elements of CBATS.

Researchers in Taiwan also translated a version of the STEBI instrument into Chinese and assessed contextual factors through structured interviews (Liu, C., Jack, B.M. & Chiu, H. 2007). Based on their finding that the number of years of years of science teaching is not associated with higher self-efficacies, they question whether Bandura's (1997) association of self-efficacy with this aspect of context is valid. Perhaps this is because Liu, et al. (2007) used a narrow interpretation of teaching contexts, limited to years of teaching science. They did not systematically examine many of other contextual teaching elements.

A longer term study which looked at self-efficacy and teaching contexts was conducted in a northern European country using translated versions of both STEBI and CBATS (Author, 2003) and then replicated in the United States with original versions (Author, 2007). Three cohorts of new elementary teachers in Europe, 86 in all, and two cohorts of US students 12 in all, completed the study. Consequently, a validity comparison between results across two cultures using analogous instruments was possible. In both countries, newly trained elementary teachers completed STEBI prior to starting to teach and then again after their first year of teaching. They also completed CBATS at the conclusion of their first year to report on the contextual aspects of their teaching environments.

For the northern European cohorts, it was found that the higher the context assessments after a year of teaching, the greater the positive changes in self-efficacy from the pre-service measures until the end of the first year (Table 1) and that these correlations increased over the course of the year.

Table 1 *Correlations of Changes in Self-efficacy among the teachers of a northern European country from pre-service, winter and spring measures with the likely presence of teaching environmental factors for all three years.*

		Changes from pre-service SE to winter SE	Changes from winter SE to spring SE	Changes from pre-service SE to spring SE
CBATS likelihood	Pearson Correlation	.098	.290 **	.324**
	Sig. (2-tailed)	.372	.007	.002
	N	86	86	86

** Correlation is significant at the 0.01 level (2-tailed)

Conclusions and Implications

Since Ford (1992) and Bandura (1986) have both strongly linked the context within which personal capability beliefs are formed, it is reasonable to suspect that at least for the northern European country teachers, such a link was operant due to the significant correlations between changes in self-efficacy and CBATS scores. Early trends in the US data also suggest such a relationship as do earlier US studies (Lumpe, et al, 2000**).** The fact that CBATS scores on both scales for both countries fall within similar ranges, suggests that the association of context with science teaching self-efficacy is similarly operant.

Consequently, the validity of using teaching contexts as contributors to the self-efficacy of elementary teachers of science across cultures is supported in the northern European teaching context, as it has been in US studies (Lumpe, et al, 2000). This also seems to be the case in Australia where 'self-image' was directly correlated with contextual items from CBATS (collegial mentoring, resources, time, administrative support and equipment) (Appleton, K. & Kindt, I., 2002). Indian findings that time and a written curriculum were significantly related to self-efficacies similarly validate the useful relationship between context and personal capability beliefs (Desouza, J.M.S., Boone, W.J. & Yilmaz, O., 2004). In Taiwan, the focus on self-efficacy as related to years of teaching without also examining environmental factors may have reduced relevant explanatory variables for found differences (Liu, C., Jack, B.M. & Chiu, H. 2007).. In each of these cultures, purposeful validity studies such as were conducted to examine the North American and northern European association between self-efficacy and teaching contexts would be useful for international comparisons.

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Effectiveness of design: Training university teachers through integration of theory and practice.

Lene M. Madsen, Frederik V. Christensen, Lars Ulriksen, Bob Evans & Camilla Ø. Rump

Research in teacher training courses for university teachers suggests that in order to ensure sustainable improvement in student learning outcomes, such courses must be designed in a way which results in a conceptual change in the participant teachers' conception of teaching, from a teacher focused to a student focused conception. It has been shown, that on the average, teacher training courses (TTCs) do in fact obtain this result. However, two research questions remain open: What activities could be included in an effective course design? Is it possible to use TTCs as levers in educational change on a larger scale? In this study we analyse six different sets of data obtained from a comprehensive compulsory course, in order to evaluate the effectiveness of the design and identify important elements. The purpose of the course goes beyond conceptual change and aims at providing participants with capabilities to participate in educational development at the programme level. Results point to elements resulting in successful integration of theory and practice, and to some success in initiating educational development. Discussions of how to assess long term effects are anticipated.

Background: Purpose of the study and problems addressed

The challenge of professional education is to plan and frame learning processes that actually promote integration of the theoretical curriculum with students' professional practice. In courses for university teachers this is not less so. In research intensive environments even interested teachers may struggle to defend to themselves and others that it is worthwhile spending time on developing and informing teaching practice. This means that teachers often enter courses with a certain impatience and a very pressing desire to get easy fixes and immediately implementable 'tips and tricks'. However, summing up the research on tertiary teacher education of the previous decade, Ho *et al* (2001) conclude that efforts to improve teaching through a 'teaching skills' approach typically failed, primarily because new faculty tended to use methods 'mechanically' and to transform them into their existing 'transmission' modes of teaching. Instead they conclude that deeper changes are needed to move from teacher-centred strategies to student-centred development.

Evidence supporting the conceptual change approach is also found in other studies, where the relations between teachers' conceptions of teaching and students' conceptions of learning have been observed. Thus, Triggwell and Prosser (1999) identified two qualitatively different conceptions of teaching: The Information Transfer/Teacher Focus conception (ITTF) and the Conceptual Change/Student Focus conception (CCSF). Empirically they found that if the teacher has a CCSF conception of teaching, students are more likely to apply deep learning strategies and hence obtain a better learning outcome. If the teacher has an ITTF conception of teaching, then students are more likely to apply surface strategies, which result in lower learning outcomes. Gibbs and Coffey (2004) show that when teachers' conceptions change to be more student focused, students apply surface strategies to a lesser extent.

While Gibbs and Coffey (2004) showed, that on the average, Teacher Training Courses (TTCs) do change teachers conceptions, and that these changes are sustained for at least one year after a course has finished, several important questions regarding TTCs remain open to further research: The effectiveness of design, what kinds of teaching and learning activities should be used (in TTCs) and what curriculum and what degree of integration between teachers' practice and course activities should be used? In addition, what are the long term effects on university teaching practices: Are the changes in teachers' practice sustained on a longer term (beyond one year), and is it possible to use TTCs as levers for overall educational development at departmental and/or programme levels?

The purpose of this paper is to analyse a TTC using qualitative and quantitative data in order to identify successful design elements and point to possibilities for further development. The course was designed with a purpose beyond conceptual change, in that one goal was for teachers participating in the course to be potential agents of change at the department and programme levels.

Research design and methodology

An overview of the structure of the TTC is shown in Figure 1. The course is a comprehensive compulsory course aimed at assistant professors and post-docs in longer term positions in faculties of science. The overall course load is 250 hours, and the course stretches over a full year. The course consists of a theoretical part with an Introduction to University Pedagogy (IUP) focussing on clarifying objectives and planning a lesson, and a more comprehensive Course in University Pedagogy in Science (CUPS), containing five central themes and two projects. The two projects are on student learning and organizing student activating teaching/learning activities, respectively. In the practical part, participants receive supervision on their own teaching both from senior staff members, and from peers (other participants). Each participant develops a teaching portfolio, with reflections and documentation, typically comprising elements from both the practical and the theoretical parts of the programme.

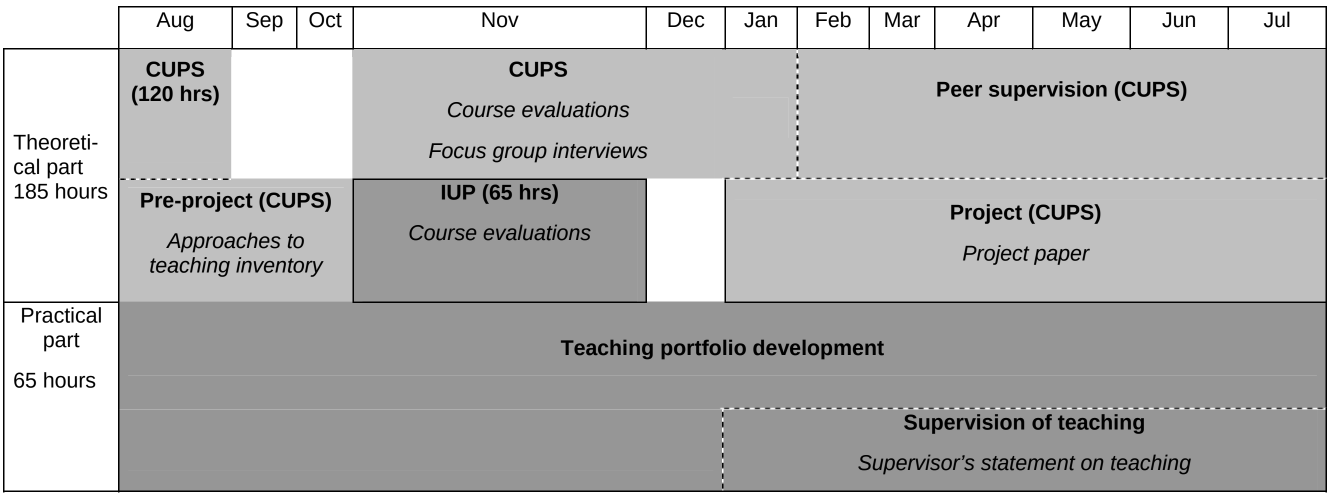

Figure 1. *Overview of the structure of the Teacher Training Course that was studied. CUPS is the Course in University Pedagogy in Science and IUP is Introduction to University Pedagogy. Italics indicate data collected and used for this study.*

In Figure 1, italics indicate the data used to evaluate participants' conceptions of teaching and their teaching practices collected in six different data sets. Most of these have been obtained from 2003-2009. In total 260 teachers participated in parts of or the full programme within the last seven years.

Three different types of data have been used in the analysis, each representing a particular perspective on effectiveness. One type is used to provide insight into the teachers' own conceptions of the outcome of the course. These data are both quantitative and qualitative and are obtained from the course evaluations. The second type of data provides insight into the teachers' conceptions of teaching through a standardized tool. These are obtained from an administration of the Approaches to Teaching Inventory (ATI, Prosser and Trigwell, 2006) twice, before and after CUPS. The third type of data provides insight into the teachers' process of conceptual change in relation to the course design. These are obtained from analyses of participants' project papers, from focus group interviews with two groups of participants by the end of CUPS, and from the supervisors' participatory observations of the participants' teaching. The different types of data and the various methods of obtaining qualitative and quantitative data allows for a triangulation of the data, as proposed by Mathison (1988). It provided insights into the process of conceptual change and development the participants went through as a result of the course activities.

Results: Data analysis and research findings

Here only results from three of the six datasets are given. In the full paper results from all six data sets will be discussed. From the IUP course evaluations we found that 71% of the participants said that they will use what they have learned “to a very high degree” or “to a high degree” (on a five point scale, 196 participants in all). Such data give an indication of the programme’s influence, however limited. In the Course in University Pedagogy in Science (CUPS) course evaluation, participants were asked to formulate what they regard as the main outcome of the course for them. In these open ended questions, the teachers pointed to general principles or approaches to teaching as well as to the possibility of sharing and discussing teaching experiences with colleagues. Even if some of the points mentioned refer to specific approaches (e.g. active participation of students, use of PBL format or formulation of teaching goals as outcomes rather than as syllabi) on a more general level the results indicate that teachers have indeed adopted a deeper approach to teaching. Finally, the project assessments show sometimes fully student focused conceptions and sometimes mixed conceptions as the following two examples show:

“Personally this small investigation has surprised me, by showing so clearly a positive effect of using active dialogue with the students during the lecture. Students learn too little if the teaching is passive. Another positive aspect I've experienced is that when the dialogue has been initiated, the students are willing to ask questions if there's an aspect they'd like to have elaborated. Such questions also provide feedback to me about the students' understanding.” This teacher is in the transition phase, but his own investigation has pushed the participant the final bit: The teacher is clearly focused on the students’ learning outcome. Another teacher states in the project:

“But it was difficult for me to get a reflective dialogue with 150-200 students, and there was often some in the back row who were sleeping or mentally absent. In CUPS, I got some specific ideas and inspiration as to how to activate students in the lectures. […] It is my clear feeling that the efforts bore fruit. There was considerably more dialogue, and more questions from students. The students seemed more vigorous and engaged, even the ones in the back row.” This year, more students passed the exam, and the teacher was elected “teacher of the year” at the faculty. While this teacher clearly had a student focus even before entering the course, the course provided with inspiration as to how such teaching could be developed.

These two examples show that these teachers have developed an awareness of the importance of the students’ perspective on learning, and ways of organizing such teaching. They also indicate the role of doing the project in the teachers’ learning process. The data furthermore include examples of teachers proposing reorganization of a whole course in terms of both curriculum and teaching methods and even a proposal for changing an entire bachelor’s programme, thereby indicating some success in the purpose of the course, which states that the participants should be able to participate in educational development. This will be elaborated on and documented further in the full paper.

Conclusion: Effectiveness of design, discussion and further research.

From analysing the data sets we conclude that the programme indeed facilitates conceptual change of learning and can provide participants with the capability to participate in course design and educational development. We can also point to particular elements in the course design which play a particular role in the learning process, e.g. the project and the use concrete examples of teaching formats, like interactive lectures, presented by experienced teachers in the faculty, and an exercise in course and programme alignment of the participants own course.

We have found that the multiple-facetted way of obtaining data on conceptual change used in this study provides valuable insights into the processes and practices of teachers learning to teach. However, we also found that discussion and the exchange of experience with different research methods and data types, between researchers within this field is a fruitful way forward to engage in further development of educational programmes. Going forward we will discuss how to address the long term effect of TTCs. Can they be used as levers for educational development on a broader scale and if so, how? We will propose in-depth interviews with participants and other informants, as well as observation of teaching practice.

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Danish secondary school students' interests in science and technology

Lars Ulriksen & Henriette T. Holmegaard

The paper presents results from a study of Danish HTX students' interests in science and technology (S&T). HTX is a three year upper secondary school programme with particular emphasis on S&T, qualifying for studies in higher education. The paper draws on a quantitative survey of 3000 1st and 2nd year students and qualitative semi-structured interviews with 25 students. It shows that students opt for HTX in a mixture of selection and avoiding particular subjects. It supports previous studies that find differences between boys' and girls' interests with boys preferring technology and girls' preferring themes related to health & illnesses. However both boys and girls favour the experimental, experiential and application dimensions of S&T. Some students like that S&T provides a sense of mastery both by making it possible to figure things out for yourself like a detective, by having the power to predict what is going to happen and that the students can figure these things out for themselves. The pedagogic format of HTX supports these interests but there may be ambiguities in some of the subjects. This calls for further analysis.

Background, Framework and Purpose

The endemic need for an increasing number of students enrolling and completing studies in science and technology (S&T) calls for closer studies of young people's interests in the field. Previous studies have analysed students' attitudes and interests (Osborne et.al. 2003) although there are some ambiguities in both the concepts used and the methodology applied (Krogh & Thomsen 2005). This paper presents results from a research project where students' interest in S&T was one of more research questions. The aim of the paper is to discuss the interests that students who actually decided to pursue this field of study in secondary school have in S&T and thereby to further deepen our understanding of young people's interests in science.

The research was carried out at 'The Higher Technical Examination Programme' (HTX), a three year upper secondary school programme that is specialised in the field of science and technology and that gives access to higher education. Students entering HTX are 15 or16 years old and have just finished nine years of compulsory schooling. This is their first educational choice.

Studying HTX students provides insight in interests of young people who pursue a study in S&T, and opens for an understanding of which elements in S&T that may appeal to this age group. The purpose of our analysis therefore is to learn about what attracts young students to S&T which may provide a broader understanding of young people's interests and experiences with S&T-teaching than just for students at HTX in Denmark.

Rationale and methods

Both interests (Krogh & Thomsen 2005, Krapp 2002) and choice of study (Hutters 2004) are complex processes that include cognitive and emotional aspects as well as the persons own and the culturally embedded images of the field. Adopting a qualitative approach in studying interests allows for an understanding of this complexity and the shades in the young's choices of fields of study. On the other hand qualitative studies frequently comprise of a limited number of respondents influencing what can be generalised. The validity of quantitative studies is however weakened by their more simple approach to the research issue.

Our study combines an internet based survey of all first and second year students from HTX with semi-structured qualitative interviews with 25 students, 10 teachers and two principals. The survey includes 3004 students, a response rate of 46 %. There is a slight overrepresentation of girls, but no bias in the size of schools or urbanity. In spite of the low response rate we conclude that the material is sufficiently robust for analysis, though some caution in the conclusions is required.

The 25 students (18 boys, 7 girls – 80 % of the students at HTX are boys) were selected on the basis of the observations in four classes. Some interviews were individual while others were done in groups. The interviews typically lasted between 60 and 90 minutes and were afterwards transcribed verbatim. The survey was analysed as simple analysis of correlations using SPSS. The level of significance was estimated using chi-square tests.

Results

In the survey students were asked inter alia why they had chosen HTX. Students could choose three of 16 statements, and responses indicate that the choice of programme is a combination of selection and avoidance. Most students mention 'interest in S&T' as a reason and second most that they need HTX for their intended further study. But the third highest ranked is that students avoid taking subjects they consider boring or unnecessary, subjects that are compulsory in the other strands of secondary school. The same duality of selection and avoidance is found in the interviews. Also students emphasise their interest in S&T combined with their being good in science (the fifth frequently selected reason in the survey).

Another question addressed what kind of S&T that interested the students the most. This question was formulated with close resemblance to the categories used in the ROSE-study (Busch 2005, Schreiner 2006), and students could select one of the categories. The results are very similar to those of the ROSE-project, including the significant difference between the interests of boys and girls.

For boys technology is by far the most popular (37 %), followed by 'science & computers' (17 %) and 'science & mathematics' (12 %). For girls 'health & illnesses is almost as clearly the most popular (32 %) followed by 'technology' (13 %) and 'science in itself' and 'science & mathematics' (both 10 %). Though boys' and girls' main interests differ, two of the girls' most popular themes are in fact the same as the boys'. Boys however show no interest in health (5 %), and girls no interest in computers (5 %).

The students were also asked what they like the most about S&T, choosing one characteristic out of a list of 11 items. Here the boys' and girls' responses were more alike. Top three for both genders are that S&T provides an opportunity for experiments and development (B: 27 %, G: 30 %), that S&T can be applied (B: 20 %, G: 16 %) and that it is possible to be creative in S&T (B: 10 %, G: 15 %). The constructive and applicable aspects seem important to a large proportion of the students.

The interviews give a more detailed picture of the students' interests. The students' crave for relating the curricular content to some application is endemic in the interviews. Students appreciate teachers who relate theoretical issues in the subjects to practical application, e.g. in building, in industry or in everyday life. The knowledge then appears to be less useless. Also students value the practical project work that is a hallmark for HTX, where students use theoretical knowledge in designing, constructing or otherwise solving problems, they have formulated themselves.

In the interviews the students tell about other aspects of their interests:

- Some of the students emphasise the 'detective-like' nature of S&T, where they use theory and methods to discover things. The students both point out the fascination of being able to analyse a given material and finding an answer and the thrill of doing it themselves.
- The sense of mastery is also important to students, both as an ability to 'figure it out yourself', and as the notion that calculations make it possible to predict what will happen.
- The interviews also convey the interests related to development and innovations. For some students it is related to a wish to conquer new land and find new ways of thinking, while others also hope that S&T will make them rich.
- The way the students talk of the human body as a field of interest suggests that it is rather an interest in how the body functions, than an interest in care.

- Finally some students point out that their main interest in S&T is the feeling of being in control and to find one correct answer to even complicated questions. These students find S&T helping them navigate in a world which is often complicated.

Even if some of the interviewed students refer to aspects of the teaching they find fun or interesting, hence a situational interest (cf. Krapp 2002), several of the interests mentioned by the students are of a more lasting nature. The students' interests relate to the school subjects and to a scope of the subjects that goes beyond the school into the world outside rather than to the subjects as scientific enterprise.

It seems that to arouse and maintain these students' interests focus should be on S&T as a means of understanding and master the world, on the application and on teaching that gives the student an experience of mastery, rather than on S&T as a research discipline.

Conclusion

Findings in the survey show that even if there are differences between boys' and girls' interests regarding themes within S&T they share interests when it comes to the characteristics of the field: The investigative, experimental and applicable aspects are valued. Thus the gender differences are indisputable, but should not be overemphasised since that may mean that the similarities are discarded.

The study suggests that at least some of the young could be attracted to S&T by a pedagogical approach that prioritise the creative, experiential and experimental aspects and that relates the school subjects to applications and the understanding of apparently incomprehensible phenomena in the world outside school. As it is, this corresponds with the pedagogical format of HTX with strong emphasis on problem oriented project work, and the application of the subjects in contexts outside school. Tentative analysis for some of the school subjects suggests that there may be some ambiguities in relation to intentions of the curricula and some subjects' cultural identities. This calls for further study.

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Didactical contract: An analytical concept to facilitate successful implementation of open-ended physics labs

Lærke B. Jacobsen, Bjørn F. Johannsen, Camilla Ø. Rump & Jens H. Jensen

What seems straightforward on paper might turn out to be complex in reality. This is a lesson often learned by educational designers when implementing variations of open-ended alternatives to traditional education and disappointedly reviewing the outcome. Based on observations of discouraging outcomes of alternative laboratory work in secondary and tertiary physics education we decided to approach the underlying cause of the problem. Framed in the theory of Didactical Situations in mathematics we adapt the concept of the didactical contract to the physics education context to locate aspects of the traditional laboratory learning environment that would lead to resistance from those involved if faced with alternatives. We conclude that both teachers and students lean heavily on a type of algorithm that ensures an appearance of having successfully completed the assigned tasks. This algorithmic didactical contract permeates through secondary education into university physics education. Our results allow for a better renegotiation of didactical contracts and thus for avoiding typical problems related to the implementation of alternative tasks. One might expect physics students to be special in their explicit interest in physics and thus plan educational activities accordingly. Based on our results, however, we find this an ill-advised strategy.

Background, framework and purpose

Laboratory work in physics education (labwork), both at upper secondary education (labwork2) and introductory tertiary (labwork3) levels, continues to be a strongly teacher-guided activity. Alternatives to the guided labwork emphasises inquiry-based, student-centred authentic tasks. When properly implemented, such shifts have been shown to better spur student motivation as well as substantially enhance learning outcomes (DeHaan 2008). However, when introducing alternative labworks, teachers and educational designers are often experiencing considerable resistance from both students and faculty involved; resistance expressed in student and teacher frustration, resignation, disappointment etc. This resistance, as well as suggestions for resolution, is plentifully reported. At the MIT Physics Department problems concerning the implementation of Technology Enhanced Active Learning in a university electromagnetism lab was ascribed to insufficient training of both students and teaching staff. In Australia a solution was found in supporting labwork2 students gradually coming to understand the purpose in terms of intended learning outcomes (Hart et al. 2000).

Having observed alternative physics labworks at both secondary and university level and experienced partial failure at both levels, comparisons of *a posteriori* analyses lead us to conclude that although student/teacher reactions to the attempts were diverse they also shared one aspect that could explain the disappointing outcomes: the alternative labworks introduced conflicts of expectations regarding learning outcomes, fostered by traditional labwork praxis.

The observed labwork2 environment required of the students to approach their own video-recordings of sporting activities from a physics perspective. The students enthusiastically took on the task, but the challenge of turning sports into physics resulted in frustrations instead of the intended engaged physics-exploration.

Given a box containing an assortment of springs and weights, students in the labwork3 setting were asked to utilize their physics knowledge to construct a time-measurer. Disappointedly teachers observed that some students felt satisfied using their watches to time their oscillating contraption. Teachers had expected the students to be ‘different’ from upper secondary students in that all would engage in using physics in an authentic context. Instead teachers saw that some students treated the task as a banal problem aimed at a quick resolution.

Rather than approaching these problems by remedying the context-specific problems (as was done at e.g. MIT), we have decided to focus our inquiry at gaining a deeper understanding of that which underlies the apparently conflicting expectations fostered by traditional labwork praxis. Inspired by the French Theory of Didactical Situations in Mathematics (TDS) we frame such aspects of expectations towards learning outcomes within the metaphorical notion of the didactical contract:

The didactical contract is the rule of the game and the strategy of the didactical situation. It is the justification that the teacher has for presenting the situation, […] a relationship […] which determines – explicitly to some extent, but mainly implicitly – what each partner, the teacher and the student, will […] be responsible to the other person for. This system of reciprocal obligation [and expectation, we argue] *resembles a contract.* (Brousseau 1997, p.31)

Thus, by applying a theoretical construct to a novel context, the purpose here is to offer important input to assisting the implementation of alternatives to traditional teacher-guided labwork at both secondary and tertiary level education.

Rationale

We focus our attention on problems of the traditional labwork praxis relevant to informing and appreciating what is at stake when replacing traditional physics labwork with alternatives.

The time-measurer task was introduced as the first labwork3 of the introductory physics course leading us to suspect that new physics students carry with them preformed ideas about how physics is taught at the university level, ideas developed in upper secondary school, expressed through the didactical contract signed in traditional labwork2 settings. Such ideas are influencing factors in the conflict of expectations related to the alternative labworks.

The research question is two-fold: (A) What aspects of the didactical contract formed between teachers and students when doing traditional guided physics labwork in secondary education give rise to a breach of contract when alternative labworks are introduced; (B) what preformed ideas about the teaching and learning in university physics labwork do new university students hold that could originate in such aspects?

Method

It is necessary to unfold the concept of the didactical contract to characterise relevant aspects of the traditional labwork didactical contract formed between teachers and students. Corresponding to the different status of the contract at micro- (concerning intra-exercise issues), meso- (concerning exercise realisations) and macro-level (concerning teaching objectives) Hersant and Perrin-Glorian (2005) have developed a concept of the didactical contract as four intertwined dimensions. These dimensions, adapted to the physics labwork setting, consist of: (1) the physics domain of knowledge (macro-level); (2) the didactical status of the knowledge (meso-level); (3) the nature and characteristics of the ongoing didactical situations (meso-level); and (4) the distribution of responsibility between teacher and student with respect to the knowledge at stake (micro-level).

The empirical basis, a purposeful spread of research-interaction (curriculum and task analysis, outcomes validation, observation, and interviews) with actors in secondary physics education, was analysed according to the dimensions of the didactical contracts. The first dimension was informed through task-analyses focusing on what conceptual, procedural and epistemological aspects students would hypothetically need to master, in order to independently complete the prescribed labwork2. The analysis of the second dimension was informed through curriculum analysis and teachers' reflections. The third dimension was informed by analysing observations, along with analyses of lab-reports authored by students and post-lab student interviews. Finally the distribution of responsibility was extracted by interaction-analyses of labwork2 video-recordings and teacher and student interviews. To inform our understanding of the macro- and meso-contract at introductory tertiary level 26 interviews were performed with new physics students at a traditional European research university, focusing on their perceived expectations of learning-activities to come. Three student pairs as well as one teacher were subsequently observed and interviewed in-action during one session of labwork3 at the end of their first semester.

Results

To characterise the relevant aspects of the didactical contract established in the tradition of guided laboratory works at both secondary and tertiary level, the data were analysed according to the scheme of dimensions (and the underlying levels) of the didactical contract, as described above.

The analysis of the data according to the first dimension revealed a complexity of demands for even simple practical works. At the apparent level of the curriculum students have to e.g. operate in and between the material world and the world of theories and models along with possessing operational abilities related to the multitudes of representations presented in labwork2.

The second dimension analysis revealed a mesh of purposes in play for educational labwork, for example expressed by teachers as confusion about the didactical status of labwork2 activities.

Observation of labworks and subsequent analysis informed the third dimension, revealing information of how students and teachers perceived the task-elements. Opposed to what was expected from the first dimension task-analyses students did not have to explicitly address the complex web of task and subtasks. Instead they were guided through the task by following a pre-rehearsed algorithm for performing laboratory work.

Regarding the fourth dimension, analysis concluded the distribution of responsibility as ‘smooth’; students and teacher felt secure of their roles and responsibilities.

Together the four dimensions lead us to the concept of an algorithmic didactical contract that renders labwork a mere rehearsal of an algorithm. If properly complied with, this algorithm facilitates curriculum content in a way that to both students and teacher have come to appear a sound and satisfactory engagement with physics content. Since the algorithm guarantees an outcome in moving away focus from the process this aspect of the contract results in a breach when alternative labworks are introduced.

Analysis of interviews with new physics students verified that students carry with them the notion that it is legitimate to approach aspects of learning physics in an algorithmic fashion. In observing and interviewing students in action half a year after commencement we ascertained this attitude towards learning in the lab - apparently originating in the algorithmic didactical contract.

Conclusions and Implications

Two conclusive characteristics of the didactical contract, each answering the two parts of the research question are highlighted: (A) The didactical contract setting of labwork2 dictates an algorithmic approach to labwork and (B) the contract is so well established that it permeates through secondary education to the tertiary education level. This result will have implications for those teachers and educators who take into account the necessity of renegotiating the didactical contract when implementing alternative labworks.

Further the pattern of contradictions between dimensions (1 contradicting 3; 2 contradicting 4) needs attention. It appears to be an indication of a hierarchical relationship across the micro- to macro-levels which, if understood, will have implications for our approach to educational change.

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New innovative exhibition concepts at science centres may lead the way

Nana Quistgaard & Anne Kahr-Højland

Is the science centre about to die – or is it kicking and alive? And if so – what kind of role does it possibly play in our society? And vice versa; how does the society influence the science centre? These are the questions framing this presentation. As a point of departure, we use a Danish example of an innovative exhibition concept facilitated by mobile phones and creating a so-called augmented reality. This exhibition concept represents a change within the science centre field going from providing science to the public in the form of definite truths, to providing a context aiming to scaffold the visitors and facilitate meaning making. On the societal level tendencies seem to point in the same direction, e.g. regarding the emphasized importance of facilitating scientific literacy, and likewise within the formal school system where critics claim that 'cookbook-like' hands-on experiments are *too* structured and fails to facilitate reflection. We argue that the relation between the science centre setting and the society/formal school system are linked and also dialectic, but that science centres are enterprising. Thereby, science centres are indeed alive and hold great potential of becoming an important contributor to the educational agenda in the years to come.

Definition of the problem

In an often cited paper from 1998 James Bradburne comes "to the reluctant conclusion that the science centre is doomed" (Bradburne, 1998). Based on the experiences gained from more than 15 years within the field of museums and science centres he concludes that the science centre's "mission no longer meets the needs of society, its relevance to the public is diminishing and it is being made superfluous by new communication technology". In later papers Bradburne (e.g., 2004) has hardened his pleading for 'a third paradigm science centre', just as other theoreticians as well as practitioners within the science centre field have been pleading for change (Pedretti, 2004; Henriksen & Frøyland, 2000). At present, by all appearances, the re-defining of the role of the science centre is undergoing discussion and the demand on critical reflection is emphasised; e.g., at The ECSITE Conference 2008[3].

Was Bradburne right then in his prediction of the forthcoming extinction of the science centre? What kind of role does it possibly play in our society? And vice versa; how does the society influence the science centre? These are the questions framing this presentation. Thus, the scope is to discuss the present state of science centres, plausible causes for this development, relations to societal tendencies including the formal school system, and finally the future role of science centres. As a point of departure, we use a Danish example of an innovative exhibition concept, termed EGO-TRAP, facilitated by mobile phones and creating a so-called *augmented reality* (Kahr-Højland, 2007).

Outline of argument

In 2007 Kahr-Højland, with EGO-TRAP in mind, points to a new tendency at science centres implying an increased personalization of the experience by combining the three elements *interactivity*, *narration*, and *virtuality* enabling a augmented reality. She suggests that this tendency marks an emerging new paradigm pointing away from both the traditional natural history museum (termed paradigm I) and the classical science centre (termed paradigm II). The traditional museum implies a predominately positivistic approach to learning (cf. Hooper-Greenhill, 1999). The classical science centre resembles that of Exploratorium in San Francisco, which at its opening in 1969 marked the beginning of a new area within museums bewildered by the Sputnik shock (Bradburne, 2004). The underlying concept is to make the visitor construct meaning through hands-on interactions with scientific phenomena (Oppenheimer, 1968).

[3] What is the science centre of 2020? Retrieved from: www.informallearning.com/SciCtrs2020Biblio.htm

The new and third paradigm termed the augmented reality science centre (exemplified by EGO-TRAP[4]) resembles that of the classical science centre but differs by emphasizing *both* the hands-on interactions allowing for the visitor to construct on her own *and* the scaffolding of the visitor by means of an open-ended structure in the shape of a digital narrative. A further difference is a focus on socially mediated learning processes and that inquiry is given priority over the providing of definite answers. Handheld digital devices such as smart- and mobile phones constitute the media facilitating the narrative and interactions with exhibits.

Against this background, the third paradigm museum represents a change from providing science to the public in the form of definite truths, to providing a context aiming to scaffold the visitors and facilitate meaning making. On the societal level tendencies seem to point in the same direction, e.g. regarding the emphasized importance of facilitating *scientific literacy* (cf. Sjøberg, 1998). The need is no longer to strengthen the scientific troops; rather the society calls for citizens participating critically in the democratic debate. This movement is also reflected in the formal school system. Osborne (2002) points to the necessity of a shift from perceiving science education as a preparation of an elite such as researchers, to a preparation for participation in society. Further, he argues that this is not happening in schools today due to a narrow focus on practical work and *doing* science. Similarly, in Denmark it has been emphasized that extensive and fruitful research regarding approaches to learning within the field of science education has not changed the way science is taught towards a constructivist approach. Science teaching is dominantly still authoritative and product-oriented (Dolin, 2005).

This trend is thus reflected both in the formal school system and the science centre but the didactic means used in the two types of learning settings differ. Within the formal school, critics increasingly argue that the widespread use of ‘cookbook-like’ hands-on experiments are in a sense *too* structured (Osborne, 2002; Hodson, 1990), whereas within the new science centre setting the trend goes towards *more* structure. In the latter, the structure is constituted by open-ended narratives (e.g., as in EGO-TRAP) as a response to the increasing critique of free-choice science centre exhibitions leaving the visitors poor help and guidance in untangling the exhibits (cf. Axelsson, 1997). At the same time, opposite trends seems to prevail. In the formal system the demand for inquiry and reflection is accompanied by a demand for standards and in the science centre the demand for more structure is accompanied by a need for more user-sensitivity and personalisation. We suggest that the two settings in fact are approaching each other demonstrating the same tendencies in each their way.

Discussion and conclusions

The question remains how the development within the two learning settings relates? Does one propel the other? As in similar matters, no clear-cut answers exist. However, taking our point of departure in the concrete case of EGO-TRAP, we see an example of a demand rising from research within the society and the formal school system. The design process of EGO-TRAP is a direct consequence of 1) the demands for new learning resources demanded by a 2005-reform in upper secondary education in Denmark and 2) research and regulations regarding the necessity of facilitating scientific literacy and critical reflection (Andersen et al., 2003). Thus, we suggest that regulations (or bylaws) stemming from society may propel the development at science centres. But a parallel process may stem from within the science centre as a response to research showing the failure of the free-choice concept due to a lack of structure.

Other relations point to an opposite direction. As discussed above, practice in the formal school system has failed to follow theory. This seems not to be the case at science centres, where several exhibition concepts around the world have adapted insights gained from research. In the case of EGO-TRAP, the innovative use of mobile communication technologies reflects an attempt to create

[4] For a more detailed description of EGO-TRAP we refer to Kahr-Højland (2007).

personalized, semi-structured, and socially mediated learning processes that will promote meaning making and critical reflection. Thus, the science centres are, compared to the formal school system, characterised by being enterprising. And the innovative practice at science centres has inspired new mobile learning materials within the formal setting. In this way the relation between the two settings is a dialectic process.

Further, research shows that the mobile phone does not constitute a barrier; at least not to the young generation (Stald, 2008; Kahr-Højland, 2007). The mobile phone has the ability to work as a transparent media. Also, we argue that the mobile phone constitutes a virtual other layer (Verbeek, 2005) facilitating personalised participation in a meaningful context (the digital narrative) due to its familiarity and computational capability.

In conclusion, we contend that the science centre is indeed alive and that the mobile communication technologies, which Bradburne regarded as a threat, hold great potential for becoming an important contributor to the educational agenda in the years to come. The new technologies have proven able to orchestrate the demands of the critical, interpreting, and complex third paradigm. This does not imply an uncritical use of mobile communication technologies as 'tin can openers' to learning processes at science centres. Rather, the challenge consists of using the mobile communication technologies in combination with for example user-sensitive structures and interactivity with the aim of framing experiences which afford critical reflection. If science centres realise their own potential as 'seismographs' in the educational landscape, the science centres hold a great potential of being trend-setting in the area of educational designs.

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Museographic transposition: The didactic engineering of a science museum exhibit

Marianne Mortensen

Science museums define the objectives of their exhibitions in terms of visitor learning outcomes, yet exhibition engineering staff lack theoretical and empirical research findings on which to base the creation of such educational environments. Here, a first step towards providing such research is reported. Museographic transposition was used as an analytical framework to investigate the development of an existing museum exhibit. The analysis yielded a descriptive model of exhibition engineering as a three-stage process in which simultaneous processes of epistemological development and museum-pedagogical development result in the curatorial brief which forms the basis of the subsequent museographic development of the physical exhibit. Examples are discussed which illustrate the use of the model in identifying exhibition inconsistencies, but also in generating new ideas for exhibition engineering. The potential for further developing the model is discussed.

Background and Rationale

The objectives of science museums are often stated in terms of visitor learning outcomes. The primary medium of a museum's educational activities is the exhibition. However, there is little research available to exhibition designers on how to achieve visitor learning outcomes, and exhibition engineering, i.e. the process of originating, developing a plan for, and implementing an exhibition, thus remains largely based on the tacit professional knowledge of museum staff rather than theoretical underpinnings or empirical evidence.

The quantity alone of museum research carried out in the last decades seems to contradict this statement. However, the applicability of this work to exhibition engineering is restricted by two characteristics: First, the focus of this work is the visitor rather than the exhibition. Second, the research seeks to describe strategies for supporting museum learning that are independent of the exhibition's content and thus broadly generalisable.

It is not surprising that museum research devotes considerable attention to the visitor; the visitor, after all, is the justification for the existence of any exhibition. However, the physical exhibition, not the visitor, is the only thing over which the exhibition engineer has direct control, and the application of findings pertaining to the visitor can only indirectly influence exhibition engineering. Furthermore, the underlying assumption of finding content-independent education strategies is that incorporating these strategies into exhibition design will precipitate visitor learning regardless of the subject matter of the exhibition. Yet, research shows that thinking and problem solving are always modulated by the content of the task at hand (Schauble et al., 2002), and as a consequence, general recommendations and guidelines are insufficient when it comes to designing teaching about a given topic in detail (Andersson & Wallin, 2006). In short, to conduct research that is applicable to the engineering of educational exhibitions, a content-specific, exhibition-centred approach is needed.

Purpose and Framework

The purpose of the study reported here is to take a first step towards a content-specific **prescriptive** model of exhibition engineering. This is done by constructing a **descriptive** model of an actual case of exhibit engineering. The development of this model is framed by the research question: *What is the nature of the constraints and opportunities which govern the putting-into-exhibition of a specific object of knowledge?*

This study analyses the engineering of the existing exhibit *Cave Expedition* from an epistemological perspective using Chevallard's (1991) notions of knowledge ecologies and didactic transposition. Chevallard uses the metaphor of ecology to describe the contexts within which knowledge exists ('lives'). An object of knowledge is adapted to its particular context ('ecology') and cannot be directly transferred from one context to the next. Instead, it must undergo a process of deconstruction and reconstruction in order to make it viable in its new context. When this deconstruction and reconstruction takes place in order to create an object of teaching from an object of knowledge to be taught, the process is called didactic transposition (Chevallard, 1991).

Applying the framework of didactic transposition to the process which creates a museum exhibit from knowledge in the scientific discourse yields the framework of museographic transposition (Simonneaux & Jacobi, 1997). Museographic transposition often comprises two moments of knowledge transformation: from the scientific discourse to the curatorial brief (an exhibition planning document), and from the curatorial brief to the physical implementation of the exhibition (Author, 2008) (Figure 1).

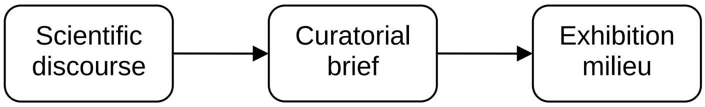

Figure 1. *Museographic transposition of an object of scientific knowledge. The object originates in the scientific discourse, is deconstructed and reconstructed for inclusion in the curatorial brief, and is again deconstructed and reconstructed to form the physical, three-dimensional exhibition milieu.*

Each of the contexts transited by an object of knowledge in the process of museographic transposition is considered a separate ecology; thus the scientific discourse, the curatorial brief, and the exhibition milieu each comprise their own knowledge ecology. These ecologies framed the analysis of the engineering of the exhibit *Cave Expedition* as described in the following.

Methods

The procedure used in the study reported here aimed to analyse the museographic transposition of the specific object of biological knowledge exhibited in *Cave Expedition*, namely *the blind cave beetle and its adaptations to its environment of permanently dark caves* (in the following abbreviated as ‘the object of knowledge’).

A preliminary analysis yielded the conditions that characterised each of the contexts of the transposition: the scientific discourse, the curatorial brief, and the exhibition milieu. For example, in the scientific discourse, e.g. within primary and secondary literature, the theme of an animal's adaptations to its environment is approached systematically by the analysis of a) the characteristics of the environment of the species in question, b) the morphological, physiological, and behavioural traits of the species, and c) the interactions between the species' traits and the environment's characteristics (cf. Culver, 1982). In contrast, the knowledge ecology of the exhibition milieu, which in this case was an immersion type exhibit, was shaped by three principles: a) the presentation of the exhibit as a coherent whole with all the exhibited objects supporting the reconstruction of a reference world, b) the integration of the visitor as a component of the exhibit, and c) the consequent dramatisation of matter and message (Belaën, 2003).

The second part of the procedure built upon the above-described elucidation of the knowledge ecologies to analyse, in each ecology, the elements of the object of knowledge present there. This content analysis thus comprised a study of the primary and secondary research literature dealing with the object of knowledge, a study of the curatorial brief *Xtremes: Storyline for an exhibition about adaptations to extreme environmental conditions on Earth* (Executive Committee, 2005), and a study of the physical exhibit *Cave Expedition*. This analysis thus yielded the content and the structure of the knowledge elements present in each of the knowledge ecologies.

Finally, the two moments of knowledge transition (i.e. from scientific discourse to curatorial brief and from curatorial brief to exhibition milieu) were investigated through semi-structured interviews with four selected exhibition engineers who had been instrumental in developing *Cave Expedition*.

Results

The museographic transposition of the object of knowledge *the blind cave beetle and its adaptations to its environment of permanently dark caves* was found to take place in two moments. In the first moment, simultaneous processes of epistemological development and museum-pedagogical development resulted in the selection of the content that formed the curatorial brief. The second moment described a museographic development in which this content was transposed into the physical exhibit. The putting-into-exhibition of the object of knowledge *the blind cave beetle and its adaptations to its environment of permanently dark caves* was thus found to be informed and constrained by epistemological, museum-pedagogical, and museographic factors at different stages in the engineering process.

According to this model of exhibition engineering, the integrity of the exhibition milieu depends on the integrity of its component parts. Ideally, each of these component parts should grow from the intersection between a specific element of scientific knowledge and a specific element of the exhibition objectives as specified in the curatorial brief. Where a component is not supported by both scientific knowledge and exhibition objectives, the component in question may undergo an imperfect museographic development and run the risk of compromising the integrity of the exhibition milieu.

Conclusions and Implications

The descriptive model of exhibition engineering constitutes a first step towards systematic studies of the process of exhibition engineering. Applying the model in its present form to the case of the exhibition unit *Cave Expedition* illustrates how the integrity of the exhibition milieu may be analysed and understood in terms of its components and their origins. The model may thus be used as an instrument with which to identify exhibition inconsistencies, but more importantly, it may be used to generate new ideas for exhibition design. Plans to investigate visitor interactions with and understanding of the exhibition unit *Cave Expedition* will expand the descriptive model of exhibition engineering into a prescriptive model for exhibition engineering.

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Travel teaches how to see – Science-teaching as navigation across borders

Martina Bruckmann, Markus Emden, Antti Laherto & Marianne Mortensen

„Travel teaches how to see": the proverb suggests that we cannot cherish a journey unless we are open to learning. Conversely, it might be true that we cannot learn unless we are ready to travel. Starting in a shared belief that science education essentially is about travelling across borders , the presenters develop their ideas of which borders there are and how they can be transcended. Analysing the subcultures of learner and learning-object indicates the border but lacks the means for crossing. Easing the transition by pulling learners into the teaching object in an immersion exhibit is one of the proposed ways in this symposium. Another one is to discuss an intrinsically interdisciplinary subject which eases learners' border crossing through disregard of traditional discipline borders. Concerning this, nano-science and -technology will be argued for from an exhibition-designer's as well as a school teacher's point of view, who wants to facilitate conceptual change. The last presentation suggests that upholding border-crossing in science learning requires teachers who are confident in this, and therefore argues for the development of special teaching materials. The symposium shows how different approaches to border-crossing might complement each other in science education.

Learning science is comparable to going on a journey in unfamiliar countries. In the same way as navigation through unknown territory may be characterised in terms of the four cardinal directions, North, South, East, and West, an educating journey through science territory can be planned using the four cardinal points of an educational compass: Guide, Traveller, Route and Destination (Figure 1). Emphasising particular directions – navigating according to certain cardinal points – will result in unique trails and different experiences along each trail.

Figure 1. The educational compass

Glenn Aikenhead likens science-learning to a journey as well. Aikenhead (1996) conceives of science teaching as facilitating the crossing of cultural borders: The learners exist in their subculture defined by peers, surroundings, etc. and they are meant to move into and within the subculture of science, which in turn is characterised by its structures and ways of working. In order to facilitate this border-crossing, science education must provide learners with the appropriate navigational aid. Depending on the individual learners (travel-groups), an educator's role might change from (prescriptive) travel-guide to (advisory) travel-agent.

Amongst the many borders that may be encountered on such a journey, we would like to focus on two: There are, on the one hand, borders that result from the intrinsic structure of the teaching-object which can be determined heuristically. When designing a teaching- and learning-journey, the teacher must decide which borders need to be crossed and which can be left unaddressed. We term this kind of border-crossing 'discipline border-crossing'. It has been argued that crossing borders between disciplines is central to scientific literacy and the demands a modern world poses on learners (cf. Bartosch & Elster, 1998; Lang, Drake, & Olson, 2006). These borders, however, must be crossed not only by learners but by instructors: To be able guides, instructors need to be ready and able to transcend discipline borders as well.

On the other hand, borders exist that do not result from the juxtaposition of science disciplines. These are limited through, for example, our potential for sensory registration or our readiness to embrace something new and 'other-worldly' (cf. Belaën, 2003, Montpetit, 1996, Fladt & Buck, 1996) that bears only little resemblance of familiarity. For the sake of distinction, we will term these 'perception borders'. In order to guide learners across borders of this type, without discomfort or insecurity, the instructor needs to identify the field to both sides of these borders. Only then can he anticipate and prepare for a smooth facilitation of the learners' border-crossing.

Each of the four presenters in this symposium strikes out on their journey taking a different course. Different philosophies of travel accompany these courses; these philosophies serve as headings in the following:

The use of travelling is to regulate imagination by reality, and instead of thinking how things may be, to see them as they are.” (Samuel Johnson)

Marianne Mortensen is ‘headed east’ because she theorises on the optimal route to a given destination. She suggests that understanding science-teaching as a border-crossing enterprise is fundamental to the design of immersion exhibits. In this special class of museum exhibits, visitors are encouraged to enter into other worlds and to perceive them from within. Applying the compass terminology, this represents a quintessential case of perceptual border-crossing. Suggestions for optimisation of such exhibits are illustrated using existing cases.

To regard only the destination, spoils the cheer of travel. (Friedrich Rueckert)

Antti Laherto discusses exhibition development as well. His presentation, in contrast to the preceding one, deals with 'discipline border-crossing' as in terms introduced above. While identifying possible routes to transcend discipline-borders in the context of nano-science and nano-technology, the direction in the educational compass (cf. fig. 1) is south-east. Indeed, the focus of the presentation is, on the one hand, understanding the interdisciplinary nature of nano-science and -technology – in our metaphor the 'destination of the journey' – and on the other hand, the means of conveying these ideas in informal education, i.e. the 'route'.

Travel is fatal to prejudice, bigotry and narrow-mindedness. (Mark Twain)

Working on nano-science, too, Martina Bruckmann has designed a teaching unit: “The size is the kick” means to ease conceptual change for advanced students in secondary schools. It simultaneously treads both border-types sketched out above but centres on guiding students across the border between the macroscopic and submicroscopic worlds. Assuming that this route due east will confirm the feasibility of that trail, she will present findings from the unit’s genesis as well as from a study on its effectiveness.

If you want to succeed you should strike out on new paths, rather than travel the worn paths of accepted success. (John Rockefeller)

As secondary schools are most likely *the* loci in which people encounter their first significant border-crossings into science, Markus Emden focuses on the design and evaluation of teaching materials. Because German teachers are typically trained in no more than two science-subjects, these materials for *integrated science* courses point west: Teachers themselves need to feel comfortable in transcending discipline borders if they want to assist students in the crossing. An evaluation study will show that supporting teachers in their own border-crossing bears positive effects on students’ achievements.

“The use of travelling is to regulate imagination by reality, and instead of thinking how things may be, to see them as they are.” Designing museum exhibits as border-crossing environments

Background and definition of the problem

Science museum exhibits are recognised as important learning environments, yet there is little research available to exhibition creators on how to achieve visitor learning outcomes. Consequently, exhibition design remains largely based on the tacit professional knowledge of museum staff rather than theoretical or empirical evidence. Here, a special class of science museum exhibits, *immersion exhibits*, are analysed as border-crossing environments to synthesise theoretical suggestions for the design or optimisation of such exhibits.

Immersion exhibits create the illusion of a time and place through the reconstruction of key characteristics of a reference world and by integrating the visitor in this reconstructed world

(Bitgood, 1990). The extent to which the visitor apprehends the exhibit's scientific meaning and message depends on the readiness with which they accept this world and the role assigned to them; a process which may be described using the notion of border-crossing. In this process, the visitor makes a transition from the visitor subculture to the immersion exhibit subculture. The immersion exhibit subculture is thus understood to be a system of meaning and symbols (cf. Aikenhead, 1996) created by the exhibition engineers for the purpose of creating an illusion of a time and place for the museum visitor. Consequently, the problem addressed by the present proposal is: *What are the exhibit design criteria for border-crossing, i.e. the successful transition of visitors into the subculture of the immersion exhibit, in a science museum setting?*

The place of the problem in the literature

Much museum learning research has focused on the visitors and their learning processes to the partial or complete exclusion of the exhibit characteristics (e.g. Falk & Dierking, 2000). Consequently, the role of museum exhibits as learning environments has long been poorly understood in the literature. More recently however, Montpetit (1996) reviewed the epistemological development of science museum exhibits from the historical diorama to present-day immersion exhibits, and discussed the changing role of the visitor in this process. From being a spectator to the traditional glass-encased dioramas and thus "at a distance of representation", in an immersion exhibit the visitor is plunged into the heart of the subject matter and is no longer a spectator, but a participant (Montpetit, 1996).

Belaën (2003) built upon this work to formulate the basic principles of immersion exhibits. According to Belaën, the integrity of an immersion exhibit depends on the accurate reconstitution of the reference world which the exhibit is based on, the integration of the visitor as a component of this reconstituted world, and the subsequent dramatisation of matter and message. The aim here is to use Belaën's work as a point of departure to formulate specific theoretical suggestions for designing immersion exhibits that succeed in creating an intended visitor-exhibit interaction.

Outline of argument put forth

As qualified in the preceding, the success of an immersion exhibit depends to a large extent on its ability to persuade the visitor to immerse themselves in it and assume their intended role. The exhibit should thus ideally function as what Aikenhead (2001) describes as a culture broker, easing the visitor's crossing of the cultural border between the visitor's world and that of the exhibit. Culture brokering entails acknowledging and respecting the perspective of the audience, making explicit the cultural border between the two cultures, and consciously and explicitly moving back and forth between the cultures during the communication event (Aikenhead, 2001). The presentation proposed here will examine the implications of these aspects of culture brokering for immersion exhibit design, and will synthesise guidelines for the original or remedial design of immersion exhibits illustrated by examples from existing museum exhibits.

Conclusions

Viewing immersion exhibits as sites of potential border crossing may shed new light on a poorly understood aspect of informal science education, namely how to optimise the design of such exhibits in terms of their ability to achieve their stated learning objectives.

"To regard only the destination, spoils the cheer of travel." Interdisciplinary aspects of nanoscience and nanotechnology for informal education

Background and definition of the problem

As more and more significant societal and economic prospects are attached to nanoscience and nanotechnology (NST), these rapidly developing fields have gained wide public interest and media attention. Consequently, various needs for educating the general public in NST have surfaced. An understanding about NST-related issues is argued to be a relevant part of modern scientific literacy (Sweeney & Seal, 2008) largely due to the interdisciplinary nature of these emerging fields. Informal learning environments, augmenting formal education, are typically interdisciplinary settings and have a significant potential to contribute to public understanding of NST. The purpose of the theoretical presentation proposed here is to discuss *how the interdisciplinary nature of NST should be addressed in an informal learning environment such as a public exhibition*.

The place of the problem in the literature

The presentation relates to the framework of informal science education, and specifically to research on science centres and museums. Most of such research is about general factors that influence visitors' learning in exhibitions (e.g. Falk & Dierking, 2000; Anderson, Lucas, & Ginns, 2003). This study, in contrast, focuses on specific exhibition content. The fields of NST are analysed in order to design an exhibition, using the Model of Educational Reconstruction (Duit, 2007) as a methodological framework. The model involves literature-based clarification of subject matter and its educational significance, drawing also on nature and philosophy of science as well as relevance of science to everyday life and society. Accordingly, in this presentation the interdisciplinary elements of NST are analysed from the critical perspective of science and technology studies (STS).

By discussing the interdisciplinary aspects in relation to the context of informal education, the presentation lays groundwork for development of a public exhibition on NST. Analysing the subject matter – its nature and structure – from an educational viewpoint is an important, yet usually neglected part of exhibition development process.

Outline of argument put forth

The presentation’s argumentation starts with general insights about interdisciplinarity in NST and ends up with implications concerning the development of informal learning environments. A lot of expectations rest on the fact that NST interlinks many traditional fields of research (Brune et al., 2006). The interdisciplinarity of NST is often referred to in terms of reductionism of the natural sciences (Schmidt, 2004); i.e. the scientific ambition is not only to link quantum mechanics, solid-state physics, inorganic chemistry and molecular biology, but to unify them as well. Some scholars have even suggested that NST should be seen as an epistemic revolution or a paradigm change (Brune et al., 2006). Furthermore, as a social element of interdisciplinarity (Schummer, 2004), communication of NST is replete with *visions*. Societal visions – related to general values or human needs such as health, wealth, security and sustainable development – provide some integration of various disciplinary perspectives.

The presentation suggests several approaches to representing the interdisciplinary nature of NST in informal contexts. Using everyday experiences as starting point, simplifying the content matter and using visual forms of communication are the apparent strategies (cf. Schummer, 2004). However, they should be used with caution. Careless simplification of the sophisticated concepts of NST, especially in quantum mechanics, leads to superficiality and risk of misrepresenting. Furthermore, oversimplified use of images in public communication of NST can mislead learners into false models of direct sense perception and epistemological misunderstandings (cf. Pitt, 2004). In the presentation, the use of reductionist hierarchies in demonstrating size scales will be discussed. Informal learning environments can also apply to an interdisciplinary approach by focusing on applications and visions of NST. However, it is argued that conception of the nature of NST can be grasped only by addressing also the epistemological and methodological issues.

Conclusions

It is argued in the presentation that interdisciplinarity is a natural starting point for education in NST. The interdisciplinary approach presents challenges to the formal educational system with traditional disciplinary boundaries in both curricula and practices (cf. Sweeney & Seal, 2008). On the contrary, characteristics of informal learning environments (Anderson, Lucas & Ginns, 2003) fit the nature of NST well. Despite several educational challenges, there are reasonable strategies to represent interdisciplinarity of NST in an exhibition.

"Travel is fatal to prejudice, bigotry and narrow-mindedness." Effecting conceptual change through teaching nano technology and perception

Background, Framework, Purpose

In order to survive, we have to find our ways in our environment. To act adequately to the situation, e.g. to flash into action when threatened, we have to receive and to process information of all the physical signals which reach us in rapid succession. This information is not merely perceived by us passively but actively gathered, filtered, interpreted and finally saved or discarded. Perception does not work unfocusedly but selectively in order for us to survive. The perception system needs to adjust together with the action system to its environment.

Aikenhead (1996) remarked that students have to challenge the border-crossing between their life-world subculture and the subculture of science. If the subculture of science fits with the student's life-world culture, science knowledge will enrich the student's view of the world. When talking about facts of the sub-microscopic world, the subculture of science is generally at conflict with students' life-world culture. Due to students' every-day experience, science courses about the character of the sub-microscopic world are more like a jump to the moon than into another subculture. In this case, students are not only required to approach the border-crossing into the well defined system of meanings and symbols of the scientific community but also to understand the other-worldliness (Fladt & Buck, 1996) of the atomic world. Our efficient human background information of material properties cannot be assigned to this other world, but we have to realign our present view on the world (conceptual change).

Rationale

Usually, students superimpose the experiences they have learned in their world directly on the sub-microscopic world. They think the world, big or small, is exactly as it meets their eyes and fits their frames of reference. This rather prejudiced and narrow-minded view of the world is meant to be widened and enriched. In order to ease this jump, we designed a teaching-unit that serves as bridge over the following borders:

Firstly, the teaching material embraces different aspects of nanotechnology. The trick in nanotechnology is to use the properties of small particles which are quite different from those of their big brothers. Students learn that reducing the size of particles changes their properties, some continuously some discontinuously.

Secondly, we bring students to look back at their macroscopic world from a new perspective. Their world, our world, is not only as they perceive it. Other beings living on different food sources and threatened by other natural enemies perceive their world, our world, quite differently from us, namely specialized in order for them to survive.

Methods & Results

In a pilot study, the teaching unit "The size is the kick" was taught in two chemistry basics courses in German secondary schools and its effectiveness concerning conceptual change was tested. Based on the experiences gathered in the teaching-unit and from assessments and questionnaires, this teaching unit on crossing the border between the macroscopic and the sub-microscopic worlds have been optimized.

In the summer term 2009, the main study will start in several courses in German upper secondary schools with the revised teaching and testing materials. The contents of the teaching material and findings on its effectiveness for the pupils as bridge between the macroscopic and sub microscopic subculture will be presented on the ESERA conference.

Conclusion and Implication

The study on the teaching unit "The size is the kick" will show that in this case, especially, "the real voyage of discovery consists not in seeking new landscape but in having new eyes." (Marcel Proust (1871-1922)).

"If you want to succeed you should strike out on new paths, rather than travel the worn paths of accepted success." Supporting teachers to transcend disciplinary borders.

Background, Framework, and Purpose

The IGLU-study of 2001 revealed for German primary students' science achievements promising results ranking Germany sixth out of the 27 participating countries (Bos et al., 2003). In contrast, PISA 2000, which examined 15-year-olds' science-achievements turned out far more sobering results with German students crossing the line 20th from 31 (OECD, 2001). It seems as if, in the progression from an integrated approach to science teaching in primary schools to Germany's tripartite secondary science education (separate lessons in biology, chemistry and physics), the momentum of children's curiosity gets lost. Therefore, most German federal states have introduced integrated science courses to their early years of secondary school in order to bridge the gap between primary and secondary science education.

Teaching materials for this reformed approach, which requires teachers to reach across boundaries between established disciplines, are still scarce in Germany. The typical German teacher usually has not been trained in the full range of science subjects. Yet, teaching shared features of the sciences might exploit powerful synergies: Theoretical approaches for experimentation, e.g. SDDS (Klahr, 2000), have already been translated into instruction paradigms arguably feasible in all science-subjects (cf. Hammann, 2004; Walpuski, 2006). Not restricting experiments to one discipline but introducing it as an overarching technique, equips learners with a competently applicable method.

Rationale

In Germany, integrated science teaching needs specifically developed teaching materials that help specialist teachers to convey an idea of generalist science. Ideally, this will preserve children's curiosity eventually carrying them into studies of the individual sciences. Teachers need additional information and guidance to feel comfortable conveying unfamiliar content.

Methods & Results

Teaching materials for an integrated science course on 'Water's many faces' have been designed relying on a previous collection of similar materials (Hübinger & Sumfleth, 2006). They have been implemented in courses for 13- to 14-year-olds and have been reworked drawing on these experiences. Likewise, recommendations from science-education researchers and science teachers have shaped these compilations. The teaching materials will have been published and distributed across Germany by July 09. Experiences from test runs will be reported at ESERA.

In a joined study, the materials' effectiveness is investigated regarding their advancement of competences in experimentation. Derived from a notion of performance assessment (Harmon et al., 1997), the study employs paper-and-pencil-tests and video-analysis of experimentation-sequences. Pairs of students, negotiating solutions of science problems, will be video-taped for this (Sumfleth, Rumann, & Nicolai, 2004). First results from a pilot study will be reported.

Conclusions and Implications

Aikenhead (1996) asks in his paper on border-crossing: "Could science curricula be developed for students identified by their border-crossing needs?" This study suggests addressing the question with a twist: As students enter secondary schools with no borders between the sciences, and as secondary schools seem to even generate these borders, science education might profit from taking secondary science teachers' border-crossing needs serious. Possibly, providing the guide with a comprehensive map of the territory helps him find the best way.

Summary

Both, practical development work and academic research on science education are highly diverse fields owing to the variety of starting points, interests and approaches (cf. Duit, 2007). The presenters in this symposium discuss this range by comparing science education to travelling in unknown terrain. They suggest that, though there certainly is orientation in the field of science education, there is not *one* cardinal path but different ones that can successfully be taken. Depending on whether an educator emphasises desired learning outcomes rather than studying his students, for example, the paths through the territory of science can be significantly differing ones.

Science education is not a jungle, neither is it a well-laid-out trip. In order to succeed, a science educator needs to decide on what he wants to achieve primarily:

- Is a certain domain of science worthwhile for all learners to encounter? – Then analyse the domain at hand and identify the defining aspects. Do away with auxiliary aspects but make sure that those retained are exemplary and represent the field well.
- Does each group of learners require its own customised path to arrive at a certain destination? – Then start by identifying the needs and wants of the group. Only then can it be decided which steps to take in creating learning environments on the topic. The way that seems easiest to the educator might not be the easiest way for the learners.
- Does the success of the journey massively hinge on the qualification of the travel guide? – In this case one might be well advised to ensure that an educator is fit for the task bestowed on him. If the educator feels unfit in any way, he cannot be expected to perform at his best and thus successful science education is jeopardized.

This symposium demonstrates that – no matter which main course is set – a worthwhile journey through science can come of it. There is not *one* golden path. Consider: When a stranger asks for directions, you usually take his needs into account and advise a different route according to what you think fitting for the stranger (the fastest lane, the most straightforward directions, the most scenic route, etc.). Shouldn't we consider a journey through science at least as meticulously?

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