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Popularity and relevance of science education and scientific literacy

The PARSEL Project in Europe

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Background, aims and framework

The European Commission concern ‘Europe needs more scientists’ (2004) was recently supplemented by the call for “Science now”(Rocard et al., 2007). Our societies, regardless of any cultural differences, need scientifically literate citizens (Bolte, 2003,2007; Brown, Reveles & Kelly, 2005; Bybee, 1997; DeBoer, 2000; Fensham, 2004; Holbrook & Rannikmae, 2002; National Research Council NRC, 1996). This is seen as being broadly consistent with the EU’s Lisbon agenda - to become the world’s most dynamic knowledge-based society. Scientific literacy furthermore stresses the social dimension, which is ...

• the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity. (OECD, 2003)

Other definitions go further and include everyday life relevance (Bolte, 2006; Holbrook & Rannikmae, 1997) and responsible citizenship (Zeidler, Sadler, Simmons & Howes, 2005). Unfortunately research shows a decline in interest in science among students, especially girls (Bolte, 2006; Gräber, 1998; Sjøberg, 1997).

A consortium of researchers from eight European nations launched the PARSEL project in order to:

• Attempt to create a network community from those working on the same topic to develop relevant and interesting teaching-learning materials
• Assemble notions of ‘best practice’ from the diversity of considerations by partners
• Develop a model which encompasses philosophical consideration, learning theories and teaching approaches
• Modify existing exemplars, as appropriate
• Evaluate examples in the practice
• Make best practice teaching-learning materials available in a range of European languages.

In a first step the crew collected 54 modules of creative science teaching, due to innovative science teaching programmes and existing experiences (Hofstein, Navon, Kipnis & Mamllok-Naaman, 2005). Other considerations are made on strategies to implement the PARSEL-Modules into teachers’ professional work (Michelsen & Lindner, 2007).

Implications

The materials go beyond scientific problem solving (even where this leads to “applications” in real life), or promotion of the nature of science. This is seen as a key feature of the model. The intended theoretical underpinning of the materials and hence the structure of the model is activity theory as described by van Aalsvoort (2004). For material to have relevance it is seen as essential that the learning meets a need, as perceived by the student, and involves motives that enable students to recognise the relevance of the learning to their lives. The model perceives the importance of initiating the teaching from real life and then pursuing the science and excluding material (especially based on the title of teaching materials) which initiate the learning through a scientific approach. The model shows this as step 1.

Step 2 is familiar to science teachers and reinforces the inquiry type investigatory approach to higher order conceptual learning, the gaining of process skills and an appreciation of the nature of science pertaining to the area of study. The key aspect in the model is that step 2 is not the first stage and its inclusion is dependent on the real life situation starting point and the conceptual science learning boundary is given by the real life situation being studied. Step 2 thus provides the background needed by the student in order to be able to appreciate the scientific background for a better understanding of the real life situation. It enables decisions to be made built on sound scientific conceptual understanding and, if the higher order teaching has been successful, to transfer the learning to the new situation. Step 2 is thus a major component of PARSEL material, but is derived from a real life, not a scientific, introduction.

If step 2 is familiar to the teacher, step 3 is much less so. This step recognises that real life situations rarely involve scientific components in their resolution and that socio-scientific argumentation plays an essential role. Step 3 thus recognises the need for science education to reach out to the real world and meet educational goals as befit a school subject which is trying to educate students. This education is more than conceptual understanding and extends to personal and social development within a science context. Step 3 recognises this and provides the opportunity to return to the real life situations from step 1 and to pursue this into decision making using argumentation teaching approaches. These bring social factors and the application of the conceptual science together.
The model is put forward in 3 steps as an approach towards ensuring the popularity and relevance of science education and specifically helping students to enhance their scientific literacy for adult life, whether this be for further education, a career, or for being a responsible citizen. The model recognises that scientific literacy is for all.

References


Investigating teacher and student understanding of the purpose of experimental work in physics

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Background, aims and framework

Lee Shulman introduced the term Pedagogical Content Knowledge (PCK) in his famous paper in 1986 (Shulman, 1986). The term has been widely accepted among science education researchers, even though there have been discussions on how to interpret and measure PCK (Gess-Newsome & Lederman, 1999; Lederman & Gess-Newsome, 1992; Loughran, 2005; van Dijk & Kattmann, 2006; van Driel, Verloop & de Vos, 1998; and others).

This study is an investigation of two experienced physics teachers and their way of articulating their aims and purposes for an experimental module in Danish upper secondary school. The definitions of ‘aim’ and ‘purpose’ used are found in the article by Hart, Mulhall, Berry, Loughran and Gunstone, from 2000: ‘Purpose’ is defined as the intention the teacher has for the activity when she/he decides to use it with a particular class at a particular time. ‘Aim’ is the often quite formalised statement about the intended endpoints of the activity.

Internationally there is a vast amount of literature discussing the goals and reasons for experimental work in the school subject physics. Lavonen, Jauhiainen, Koponen and Kurki-Suonio (2004), have made an extended literature review of reasons for experimental work, giving the following list from a variety of people like Hodson, Gott, Duggan, Wellington, Confrey, Millar, Wilkinson and others: Better acquisition of scientific knowledge, better understanding of the empirical nature of the natural sciences; developing different work or process related skills (measuring and designing an investigation); better attitudes and motivation to study science; enhancing personal growth by conducting experiments in the classroom; increasing autonomy when engaged in open-ended problems; connecting learning with concrete experience and more. This list is general and does not refer to special subjects within physics. If a teacher is asked generally for the reasons for experimental work in physics, parts of the above list might be given - not necessarily connecting it to their own teaching. Therefore I find it necessary to study specific experimental modules and question the teachers for their purpose(s) of their specific modules to make it more likely that the answers are connected to the action in class. I am not looking for a teacher’s list like the above, but I wish to investigate how teachers define the purposes of their experimental modules, and what impact this has on the students’ motivation and learning.

Methods and samples

The teachers were interviewed prior to the modules. Teacher 1 was teaching the ideal gas law, and teacher 2 was teaching conservation of mechanical energy. The teachers were asked for purposes for the lesson series and how these ideas were developed. The topics of these two lesson series are quite different and draw from different parts of the physics curriculum. I found it important to let the teachers choose the topics themselves, thereby giving me the chance to investigate practical work, which is special to the teachers, thereby increasing the opportunity for the teacher to show me an experiment, where he/she has given the purpose a great deal of thought.

The modules of the two different teachers were videotaped. During the practical work, both teachers had divided the class into groups of 2-4 students. During the practical work, the students worked from a teacher-written guide, and each practical work was run like a cook-book exercise with almost no freedom of choice in the performance of the practical work. Both teachers circulated, helping with practical problems and answering questions during the practical work. The students’ work with the laboratory equipment was videotaped, and they were interviewed in their groups immediately after the laboratory work. The students’ experimental reports were collected after correction by the teacher.

In Danish upper secondary school (year 10-12) the subject physics is optional in year 11 and 12. Practical work has a rather high priority in the physics class. These particular classes are year 11 students with physics on level A or B, which means they have chosen physics beyond the obligatory level. Most of the students have also chosen mathematics on level A. When asked for the future plans for education, most of the students had no intention of studying a subject where physics on a high level was compulsory; only a small percentage had the intention to study physics or physical engineering at tertiary level. The teachers have been teaching physics the last 15 and 35 years, respectively, both having taught the chosen topic many times before.

The data consist of pre-interviews with the teacher, the teacher-written guide to the practical work, video-recordings of the lessons and the practical work, student interviews, written reports and the teachers’ comments to the reports. A list of possible purposes for the topics was made, each purpose categorized as knowledge, competence and understanding (including meta-understanding and nature of science). A triangulation between the possible purposes of all these different data formats were done, showing where and to what extent the purposes correlate.
Results
During the pre-interview with teacher 1 she states that this specific module on the ideal gas law has been included in her teaching of year 11 physics a number of times, and she explains, each year the module is modulated to fit the class and is changed based on experiences from the previous years. The development of the purposes of the module has evolved during time, and it would be impossible to start out a new module with a clear plan for the purpose. This teacher hereby states that her PCK is bound to specific modules/topics, and it is necessary to teach the same module a number of times to develop and articulate the purpose of the activity. She also states that not all her modules have a clear purpose, since it demands a lot of thinking to fully grasp the possibilities within a module.

The teacher explains her purposes of the module: knowledge of the ideal gas law; skill training of graphical interpretation of data; and introduction to variable control. By variable control the teacher explains, in this example, the need to keep two of the four variables in the ideal gas law constant, change the third variable and measure the fourth, since changing three variables at once and measuring the fourth will not give the students the possibility to extract the ideal gas law from the data set. Introducing the topic to the students, the teacher writes her purposes for the module on the board. After this introduction, the list is no longer mentioned in the class, but many indirect references can be found in the teacher’s statements in class and in the guide to the practical work. The laboratory work included three experiments to be performed, which combined makes it possible to extract the ideal gas law. When asking the students, at the interview by the end of the module, what the teacher wanted them to learn, both interviewed groups were able to explain the teacher’s purposes of the module. One group referred to the teacher’s introductory list on the board, while the other group apparently had forgotten the teacher’s list but was able to explain the three purposes with their own words. The purposes stated by the teacher are again found in the students’ reports.

During the pre-interview with teacher 2, the purposes of the practical work are not prior articulated by the teacher. Clearly this teacher finds no need to articulate the purposes for his practical work beyond the aim of teaching conservation of mechanical energy, and the related physical concepts involved in this. He has a less articulate understanding of his own development of PCK. Still he explains he changes the lessons of this topic according to the interests amongst the students of the class. From the video-recordings of the lessons and the written guide, it is clear that the teacher could be using this topic to teach the students about units, uncertainties and reliability of data. The practical work involves a measurement of the change in kinetic and potential energy of a system containing a cart on a hover bench, being pulled by weight, connected to the cart by a string moving over a pulley. In the student interviews none of the students were able to explain what the teacher wanted them to gain from the practical work, besides the aim of learning about conservation of mechanical energy, and this is again found in the reports.

Generally both classes consist of highly motivated and skilled students. Both students comment on their teacher in a very positive manner.

Conclusions and implications
This synopsis is the introductory work of a larger study of teachers’ abilities to declare the purpose for specific experimental activities, both for themselves and their students. The investigation will lead to an analysis of the students’ understanding of the teachers’ purpose and the connection to their motivation and learning outcome of the experimental work.

The students of the two classes were given a traditional task of a closed experimental exercise, which is often highlighted as boring, lacking learning outcome and giving the student poor chances to gain ownership of the task. Both classes replied positively on the task, showing high motivation of each group. But it was quite different what the students of the two classes learned. The class of teacher 1 learned, beside the aim of knowledge of the ideal gas law, variable control categorized as nature of science, along with the competence of graphical representation. The class of teacher 2 learned the aim of knowledge of conservation of mechanical energy, but there are not clear correlations among the students of any understanding of nature of science or gaining of competencies.

From this study it is clearly found, that the students have a remarkable sense of understanding the intention the teachers have for the practical work. If only the aims are found important by the teacher, then only this is found in the work of the students. If the teacher is using the practical work to teach the students competencies, understanding and meta-understanding, and nature of science, then the students realize these purposes and try to learn according to them.

If this conclusion is valid in future investigations, this demands teachers to be aware of their purposes. It might seem a fairly easy task, but based on this study, literature studies of PCK and other qualitative investigations, it takes experienced teachers with a large degree of content knowledge, pedagogical content knowledge and understanding of the possible purposes of the practical work to fully grasp the possibilities, that lie within a curriculum requested task.
Kan web-logg brukes for å koble praktisk arbeid til arbeid med teoretiske begreper?

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**Innledning**

Disse forfatterne beskriver betydningen av diskusjoner i klasserommet som læringsarena. Imidlertid er skolenes IKT-park i dag så god at man kan inkludere bruk av internett-basert kommunikasjon for også å legge opp til diskusjoner mellom elever på ulike skoler, både i eget land og i utlandet. Bruk av IKT aktualiseres videre ved at det er et kommunikasjonsmedium som de fleste elevene er svært godt kjent med og liker å bruke. I tillegg skriver de da for et reelt publikum, ikke kun for en lærer som skal etterprøve hva de kan. Dette kan fremme motivasjonen for å gå inn i faglige diskusjoner. Bruk av web-logg gjør det dessuten lett for læreren å følge elevenes utvikling i bruk av begreper, på samme måte som ved skriving av logg, og å bruke dette i den videre undervisningen av faglige emner knyttet til et gitt tema.

I studiet som her blir diskutert, arbeidet elevene praktisk innenfor teknologi og design med å konstruere et fartøy som kunne kjøre på is og drives av vind. Samtidig skulle de beskrive sine planer og sin arbeidsprosess på en web-logg som ble laget spesielt til arbeidet med prosjektet. Teoretiske emner som det var naturlig å arbeide med knyttet til konstruksjonene, var friksjon, energi og vindkraft.

Studiet er en del av et større samarbeid med skoler i Australia. Dette krever at elevene kommuniserer på engelsk, noe som selvfølgelig var en ekstra utfordring for norske elever. Australia er interessant å sammenligne seg med siden de har et vestlig skolesystem, etter modell av det britiske, men de greier seg likevel bedre enn de fleste vestlige land i de store internasjonale undersøkelsene (Kjærnsli, et al., 2007).

Studiet omfatter først en utviklingsdel der et elevprosjekt med webbasert kommunikasjon mellom elevene ble utviklet. Med basis i arbeidet med disse elevprosjektene stilte vi så følgende spørsmål:

- Er det forskjeller mellom elevene i Norge og Australia i bruk av bloggen?
- Hva kommuniserer elevene på nettsidene?
- Bruker lærerne elevenes praktiske arbeid med å bygge fartøyer og deres web- kommunikasjon som basis for å arbeide med teoretiske begreper?

**Material og metoder**
Skolene som var med i den norske delen av prosjektet er:

- en 1-7 skole i Alta der en elevgruppe på 25 elever på 6. årstrinn var med.
- en liten 1-10 skole utenfor Hammerfest der 3.–7. årstrinn deltok i arbeidet med prosjektet, til sammen 15 elever.
Materialet som her blir presentert, består av en kvalitativ vurdering av elevenes bruk av web-loggen, samt en analyse av innholdet i elevenes beskrivelser på bloggen som blir klassifisert i fire kategorier i samsvar med Lloyd og Duncan-Howell (2008). Disse er:

- Deskriptiv beskrivelse av aktiviteten
- Planer for videre arbeid (viser at elevene er inne i en designprosess)
- Beskrivelse av utprøvinger
- Beskrivelse av samarbeidet i gruppene

I tillegg ble involverte lærere intervjuet etter at elevprosjektene var over. Fokuset var hvorvidt lærerne hadde lagt opp til faglige diskusjoner i tilknytning til elevenes praktiske arbeid.

**Resultater**

Det ble utviklet en hjemmeside for prosjektet:


Dette er en omarbeidet versjon av den australske hjemmesiden:


Elevene brukte informasjonen på hjemmesida som utgangspunkt for byggingen og fulgte kravene som var satt der. En av skolene, den med 15 elever, brukte ikke blogg funksjonen. Elevene ved den andre skolen brukte bloggen som en ordinær logg i etterkant av utført arbeid.

Angående innholdet i elevenes blogg så var 45% en deskriptiv beskrivelse av arbeidet de hadde gjort, 23% beskrev planer for videre arbeid, 3% beskrev utprøvinger og 29% fokuseste mest samarbeid i gruppene. Elevene har i liten grad gitt skolevitenskapelige forklaringer som begrunner deres valg og problemløsninger.

Lærerne diskuterte i oppstarten av prosjektet hvilke materialer som gav ulik grad av friksjon. Ut over dette ble ikke elevprosjektene brukt til lærerstyrt arbeid med faglige begreper.

**Diskusjon og konklusjon**

De norske elevene forholdt seg til web-loggen på en annen måte enn de australske (Lloyd & Duncan-Howell, 2008), ved at de australske elevene i større grad brukte bloggen som et diskusjonsforum. Vi ser to mulige forklaringer på dette. De involverte norske skolene har lang erfaring med å hente informasjon fra nettet, men de har liten eller ingen tradisjon for at elevene bruker nettet interaktivt i forbindelse med sine prosjekter. Dette argumentet blir forsterket av at engelsk kan være for vanskelig for flere av elevene å kommunisere på i faglig sammenheng. Den andre forklaringen er knyttet til at vi hadde tekniske problemer med bloggen i begynnelsen av prosjektet. Elevene måtte derfor i starten skrive sine kommentarer på skissene de lagde. Det kan ha ført til at det ble mer naturlig for de å fortsette med papir og blyant også utover i prosjektet.

Angående innholdet i elevenes blogger så fant vi en samsvar i fokus mellom elever i Norge og elever i Australia ved at elevene i begge land fokuserte beskrivelse av det de hadde gjort i arbeidet med fartøyene og de fokuseste samarbeidet de hadde i gruppene (Lloyd & Duncan-Howell, 2008). Imidlertid fokuseste norske elever sterkt sine videre planer for arbeidet mens de i liten grad la vekt på å beskrive utprøvingene de eventuelt hadde gjennomført. Dette forholdet var omvendt for de australske elevene.

RESULTATENE FRÅ ET SÅPASS LITE MATERIALE KAN IKKE GENERALISERES. IMIDLERTID INDIKERER ERFARINGENE AT INTERAKTIV WEB, I ALLE FALL I DISSE TILFELLENE, I LITEN GRAD KUNNE BRUKES TIL Å UTFORDE ELEVENE TIL Å BESKRIVE SIN FORSTÅELSE AV VITENSKAPELIGE BEGREPER OG FORKLARINGSMODELLER. PÅ DEN ANNEN SIDE GAV ELEVENES BESKRIVELSER ET GODT GRUNNLAG FOR LÆREREN, OM EINN LITE UNTYTET DENNE GANGEN, TIL Å UNDERVERE BEGREPER OG SAMMENHENTER MELLOM DISSE UT FRÅ DE ERFARINGENE SOM ELEVENE HADDE BESKREVET. Dette stemmer godt med eksempler Mortimer og Scott (2003) beskriver i sin bok, altså at læreren må gi den vitenskapelige fortellingen. Skal teknologi og design, i tillegg til sin egenverdi, også støtte arbeidet med teoretiske begreper i realfagene, så må læreren være faglig guide i dette arbeidet.

**References**


Selected aspects of virtual laboratories and remote experiments

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Introduction
One of the intellectual challenges when learning physics is to understand the role of a physical theory, the role of a physical model and the role of an experiment. Often, these terms are intermixed, and the classical curriculum offering separate lectures for theoretical and experimental physics does not make it easier for students to really comprehend their interrelation.

Modern eLearning technology may act as a bridge: on the one hand, computer systems make real experiments available over the Internet, anytime, anywhere, and even more important make the measured data electronically available for further analysis. On the other hand, a model for an experiment can be implemented as a simulation within a virtual laboratory, making the same physical quantities available for measurement as in the "real" experiment. It is now straightforward for a student to compare the outcome of the two approaches and to compare them again with an analytical result of a physical theory. Thereby, similarities and differences between the theory, the model and the experiment can be demonstrated and analyzed.

In this paper, we discuss two important physical systems. Firstly, the physics of ferromagnetism and the Ising model [1] as the most prominent system of statistical mechanics. Second, the physics of ideal gases, and, as the corresponding theoretical model, the lattice gas model [2,3] to discuss the concept of entropy phenomenological as well as statistical thermodynamics.

Related works
Remote experiments and simulations are actively used in various experimental sciences, related training courses have also been explored in chemistry, see e.g. [14] and electrical engineering, e.g. by [15]. However, the relation between experiment and simulation is rarely stressed. The combination of complementing virtual labs and remote experiments supports the analysis of a given physical phenomenon from different angles. The capability of remote access through the Internet allows the student a direct comparison of theory and model on one hand and experiment and physical reality on the other without having to switch back and forth between library or Internet and the laboratory. An interesting and related setup is the remote experiment and virtual lab for wind tunnels developed by Esche et al. [16], a virtual laboratory for exploiting DSP algorithms [17], and a learning tool for chip manufacturing [18]. Virtual labs are also explored as onshore educational tools to train the technical skills of sailors of the US navy, see [19].

Magnetism in virtual laboratories
The Virtual Laboratory VideoEasel developed at the TU Berlin focuses on the field of statistical physics and statistical mechanics [7,8]. Implementing a freely programmable cellular automaton [9], VideoEasel is capable of simulating various models of statistical mechanics and related fields.

Measurements are performed by tools freely plugged into the experiment by the user, allowing to observe magnetization, entropy, free energy or other measuring quantities. When experiments of higher complexity are performed, the experimental results can be automatically exported into computer algebra systems for further analysis. To enhance cooperative work between students, or students and their teachers, VideoEasel is able to support distributed measurement processes on the same experimental setup, including remote access from outside the university [7].
To investigate the Ising model, VideoEasel implements the Metropolis dynamics (Figure 1) [10]. A spin is drawn at random, and flipped if either the overall energy of the model decreases after the flip, or the energy can be borrowed from a heat-reservoir. The user is able to control the temperature $T$ and external field $H$ and then measures quantities as the magnetization $M$. If we plot the relation between $M$ and the field $H$ for low temperature, a hysteresis loop is found (Figure 2). For high temperatures this figure vanishes.

Additionally, our model allows us to measure an additional parameter, namely the Helmholtz Free Energy $F$.[11] This quantity is phenomenologically defined as the fraction of the overall energy of the model that is available for mechanical work. If we measure $M$ and $F$, each depending on $H$, while starting from a random spin configuration, we get the graphs shown in 3. It is now easy to conjecture for our students that $M$ must be proportional to the negative derivative of $F$ with respect to $H$. After having seen that, our students easily derived this from the Gibbs state of the Ising model [11], and thus our experiment was also didactically successful.

Investigating hysteresis in remote experiments

Complementary to virtual laboratories, remote experiments are real experiments, remotely controlled by the student from outside the laboratory. A remote experiment consists of two vital parts, namely the experiment itself and a computer interface allowing control over the experiment via the internet. For the latter, we use National Instruments LabView [12], which also provides a convenient web-interface. In order to view and control the experiment, a freely available web browser plug-in has to be downloaded and installed. Due to the modular programming structure of LabView, remote experiments can easily be combined or extended [13].

We can now run the same experiment, namely that of measuring the hysteresis loop of magnetization vs. magnetic field, in reality: a magnetic coil generates a magnetic field $H$ that is proportional to the current passing through it, which is controlled by the computer. The magnetic field magnetizes a ferromagnetic core. The magnetic induction $B$ is measured by a Hall probe (Figure 4). The measured value is then digitized by an analog-digital converter that provides a digital output port, and by that made available from the computer system.
Virtual laboratories and remote experiments: similarities and differences

At first glance, both the experiment and the model show the same hysteresis effect: the relation between magnetization and magnetic field cannot be represented by a function. However, a student running both types of experiments will note that the exact shape of the hysteresis loops is very different: Whereas the Ising model shows an almost rectangular shape (Figure 2), textbooks typically show an S-shaped form. But even the usual graphs found in textbooks do not always depict reality correctly: The hysteresis loop has a small area (Figure 5). Thus experiment and model do not agree completely.

There are also deviations between model and theory: When taking the numerical derivative of the free energy, the curve looks almost, but not quite like the magnetization plot: The derivations are best seen for small fields. This is likely because our entropy measurement is only an approximation and does not take long-range interactions into consideration.

Students, in this way, learn that models are by their very nature incomplete, and theories make approximations and can only predict reality within a certain error.

A brief introduction to thermodynamics

Thermodynamics is the physics of temperature and heat. As a phenomenological science, it formulates the relations observed between physical observables. For example for the ideal gas the product of pressure and volume is proportional to the temperature. Thermodynamics does not attempt to derive these relations from a microscopic theory.

Even though these relations are obvious to verify in an experiment, thermodynamics also formulates laws that are harder to verify experimentally. The most prominent example is the second law of thermodynamics, first formulated by Clausius [20], which states the existence of a thermodynamic potential called the entropy, which cannot increase in closed systems. One of the consequences of this law is that thermodynamic processes, e.g., combustion engines transforming heat into mechanical work, must have a limited efficiency strictly below 1. Said another way, it is impossible to convert heat energy into mechanical work without any loss [21] of temperatures $T>0$.

Since entropy is a rather abstract concept that cannot be measured directly, this law is, almost traditionally, hard to motivate to students. Some textbooks even joke that "students usually only believe this law because they wouldn’t otherwise pass their exam" [22].

Phenomenological thermodynamics in the remote experiment

To demonstrate the classical gas laws, our remote experiment farm also includes an experiment on thermodynamics (Figure 6). A motor controls the position of a piston in a glass cylinder containing air whose temperature can be remotely adjusted by a heater. Sensors measure the pressure of the gas and its temperature. Their measurements are digitized and made available over the internet. Given this setup, students can readily verify the classical laws of phenomenological thermodynamics, for example the Gay-Lussac relation between volume and temperature.
However, one can clearly go beyond this experiment: By controlling the heater and the piston, students can run the system in a thermodynamic cycle process. The amount of heat energy induced is known due to the characteristics of the heater, and the amount of mechanical energy made available by a cycle can be computed from the area within the $pV$ diagram [22] as measured, (Figure 7). Comparing the two readily presents the limited effectiveness of the process, and demonstrates one of the consequences of the second law of thermodynamics.

**Lattice gases in the virtual laboratory**

Lattice gases are simple, discrete models for ideal gases defined as cellular automata [9], and as such easily implementable in our virtual laboratory. Within HPP model used by our setup [23, 24], the gas consists of elementary particles, atoms called in the following, which can only travel in four diagonal directions within two-dimensional space. Collisions with boundaries and between atoms preserve energy and momentum.

Unlike in remote experiments, we are now in a position where we know the microscopic state of the system exactly, and are thus able to measure the entropy. In a simple experiment, a student fills one corner of a simulated gas container with the lattice gas. If the simulation is run, the gas expands into the entire container and the entropy increases except for some small derivation, see Figure 9.

![Figure 6 The hysteresis loop, as found by the remote experiment.](image)

![Figure 7 A $pV$ diagram, as measured by the remote experiment](image)
The monotonicity of the entropy looks even more surprising if we recapitulate that the elementary laws of the HPP gas are completely symmetric in time. The very same argument has been considered historically by Loschmidt as an objection against Boltzmann's H-Theorem \[25,26\]: Students are now, however, in a position where this objection can be discussed within an experiment, as our virtual laboratory provides means to invert all moments. Quite as one might expect, gas atoms then move back to their initial positions and the entropy function decreases.

An experiment, whose outcome is as confusing, is well-suited to stimulate a vibrant discussion amongst our students. The resolution is now that the initial state of a gas running back into its container is extremely unlikely and with some guidance, students often come up with an experiment to justify this argument: After modifying the seemingly chaotic state by displacing a single atom by one pixel, we invert the moments of all gas atoms again and observe the entropy and the system behavior again. Even though the entropy starts to decrease for a short while, the system comes no longer close to the initial minimum, and entropy begins to increase shortly after.

Comparing remote experiments and virtual laboratories

It is worth noting that the $\int p \, dV$ looks again not very much like the idealized curves found in textbooks and is rather noisy. Good textbooks like \[22\] will of course comment on such specialties. Similar differences often arise in real experiments, as we already found for the hysteresis experiment. They need to be discussed with the students and make up an important part of the education in physics, too.

On the other hand, we also find a tiny discrepancy between the phenomenologically formulated second law of thermodynamics and the corresponding outcome of the virtual experiment: It is not impossible that the entropy decreases, it is just that all odds are against it. Thus, the important lesson to be learned is that the second law makes a statement about the statistics of the system.

The complementary nature of remote experiments and virtual laboratories becomes even more apparent for the experiments on thermodynamics: While the remote experiment is targeted at the phenomenological side of thermodynamics, virtual laboratories allow exploring the statistical mathematical aspect of entropy. Thus, the dual nature of thermodynamical variables such as entropy - being a phenomenological quantity as well as a statistical one - can be explored and demonstrated.
Deployment and evaluation
We deployed the virtual laboratory in the course “Mathematical Physics II” at the TU Berlin. This three-semester course covers in its second semester models of many-particle physics, specifically the Ising model and the lattice gas model. Even though this course is taught in the institute for mathematics, the majority of participating students are typically physicists; the group size is typically between 15 and 20 students. While the lecture covers the theoretical aspects and the mathematical background of the models, we used the practice group of the course to guide the students to experiments on the theory discussed in the lecture before. Specifically, the Metropolis dynamics of the Ising model got introduced, the phase transition was measured on the virtual experiment and the relation between magnetization and free energy was derived experimentally. Students were asked to carry out the experiments, perform the measurements and collect all necessary data, and were requested to put this data in relation to the material learned in the lecture. To our delight, students did find the requested relation between the two quantities (see section III and Figure 3), and were able to derive them by their own from the mathematical model.

At the end of the course, we requested students to fill out an anonymous query form on the lecture and the practice group. This standard form is kindly provided by the student union of the TU Berlin, and used consistently for the evaluation of all lectures of the institute. According to this evaluation, the lecture received an average grade of 1.7 on a 1 to 6 scale, 1 being best and 6 being worst, thus placing this lecture in the best third fraction. Students appreciated mostly that they could relate the theoretical material and models to practical experience and could gain some hands-on approach on the abstract definitions learned in the mathematical course. Interestingly, the course also triggered some interest in the actual implementation and infrastructure of our virtual laboratory which we couldn’t delve into in the group due to time constraints.

Even though experiments on the lattice gas have often been demonstrated to students with great success, we have not yet had the chance to discuss the model in a similar experiment, unfortunately.

Conclusion and outlook
The accomplishment of experiments in eLearning scenarios touches many aspects of the learning process in the academic education of natural and engineering scientists, ranging from the actual quantification of a physical measurement over operating experience with real experimental setups to the examination of the corresponding theoretical model. The combination of real experiments with virtual laboratories creates many benefits, of which the most important is that we allow students to study a physical phenomenon through experiment, model and theory. We believe that the complementary nature of remote experiments and virtual laboratories stimulates the process of understanding in an outstanding matter, which is vital for the learning process in natural sciences.

Our work will also continue into another direction, namely in trying to perform experiments where virtual and real components interact, for example to compare their outcomes in a common plot within Maple, the mathematical algebra program. As both LabView and VideoEasel provide the necessary interfaces to export data, this goal seems to be in close reach.

References


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**Textbook authors’ intentions and ideas when writing upper secondary biology textbooks in relation to nature of science**

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**Background, aims and framework**

This study is part of a research project about teaching and learning genetics with a model-based approach to science and science education in which aspects of nature of science (NOS) are made explicit by the history of science. The national Swedish curricula for the science program (age 16-19) at upper secondary school (The Swedish National Agency for Education, 2007) states:

Model thinking is fundamental for all disciplines of natural science as well as other scientific fields. In education a development of understanding that our comprehension of natural phenomena consists of models…should exist. These models change and refine as new knowledge emerge. A historical perspective contributes to illustrate the progress the science disciplines have gone through and their importance to society.

Hence, this statement emphasizes the importance of using models in NOS as well as history of science perspective when teaching science.
In a first study (Gericke & Hagberg, 2007) five historical scientific models of gene function were defined and analyzed. Each model represents a significant change in the way the function of the gene was perceived. When teaching, science models are often used. However, teachers and textbooks are not always explicit about their use of models. Instead of using specific historical models, attributes are often transferred from one model to another, resulting in hybrid models that might be difficult to teach and to learn (Justi & Gilbert, 2000). In a second study (Gericke & Hagberg, in prep.) Swedish biology and chemistry textbooks for upper secondary school were analyzed in order to find out how the description of the phenomenon of gene function was presented in relation to the historical models. A great variation was found, mainly implicitly presented. An explicit NOS perspective in the books could constitute a guide helping the students to interpret the variation, and the incommensurability that might arise from this variation.

In this study we aim at:
• finding out how and why the textbooks have been worked out as they have regarding NOS
• elucidating the authors’ intentions and ideas behind them, particularly in relation to the subject matter content of genetics.

Methods and samples
Five interviews were conducted with authors representing all five textbooks, which are published in biology for upper secondary school in Sweden. A semi-structured interview, consisting of three phases: a warm-up phase at the beginning, the main phase, and a debriefing at the end, was designed according to Kvale (1996). The interviews were recorded. In the warm-up phase the interviewer explained the purpose and the procedure of the interview and the authors were asked about their background. In the main phase the authors’ incentives and motives as textbook authors were discussed. Further the process behind the writing of the textbook was elucidated. The authors views of the importance and role of NOS in general and models in particular in science education were discussed. Specific citations in the Swedish curricula about these aspects were used as a starting point in the discussions. At the end of the main phase more content specific questions regarding genetics in the textbooks, and the categorization of implicit textbook models of gene function (Gericke & Hagberg, in prep.) was discussed. During the debriefing in the end the recorder was turned off and the authors were given the opportunity to comment on the content as well as the procedure of the interview. The authors again gave permission to use the recordings for research purposes.

The interviews were transcribed and validated by a second researcher who listened through the tapes and at the same time double checked and commented the transcriptions.

Results
The analysis is still in progress so we will here present some preliminary, tentative and general results, which we nevertheless consider interesting and worthwhile sharing with others. We expect more results to emerge from the data which then will be presented at the conference.

The results show that the textbook authors can all be regarded as very insightful in issues regarding epistemology and NOS. All of them have experiences from postgraduate studies and most of them have a PhD. They also have long personal experience from teaching. The experience from teaching was by the authors considered as a very important foundation when writing the textbooks. The syllabus in biology was mentioned as an important guideline for what content to put into the book. Though other more general elements of the curricula in which NOS aspects are manifested, such as program goals for the science program and goals for the biology subject, were not considered by the authors in the writing process instead NOS aspects were handed down to the teachers to manage in the classroom. The flexible use of the textbook was much emphasized by the authors as an important goal when writing the book, making it possible for the teachers to use the textbooks in different ways not being forced to read the book from first to last page. In the idea of flexibility most authors also included that the textbooks should be regarded as a sort of base in the classroom which the students should be able to read without any instructions. Hence most authors were reluctant to include content that does not follow the main scientific ideas. More new scientific ideas that render a greater risk of being proven wrong were therefore deliberately avoided by most of the authors. The textbook may in that case soon after printing contain errors and therefore appear out of date.

Although aspects of NOS, such as models, theories, scientific thinking etc., are rarely mentioned with explicit terminology in the books, these aspects are inevitable embedded within the content knowledge (Gericke & Hagberg, submitted). A couple of the authors say they try to hint the difference between “scientific knowledge about nature” and “nature itself” by using the language as a tool. For example instead of writing “How something is” they could write “Some researchers look on it that way and other in some other way” or “A food chain shows the energy flow in a ecosystem” instead of “The energy flows in a food chain”. Four of the authors addressed the conflict between being explicit with NOS aspects and the goal of simplify the content of the book. Several of the authors mentioned that publishers requested the authors to use scientific terminology moderately. The most important aspect of NOS emphasized by the authors is the empirical basis of biology (and genetics) and that those aspects are shown by incorporating observation and experimentation in teaching, which most of the authors equals with scientific method. In the textbooks this is manifested through short
general unites about the nature of biology and in the passages describing history of science. One textbook though contains guidelines for laboratory and experimental work. However for the other textbooks there is the possibility to buy extra materials with experiments and exercises. Other guidelines to the textbooks are scarce and general.

Conclusions and implications
The textbooks influence both the structure and the contents of the lessons in high school biology (DiGisi & Willett, 1995). Knain (2001) reported that secondary science textbooks do not present science as an endeavor involving debate and discussion. The textbooks ignored the difference between “scientific knowledge about nature” and “nature itself”. Instead textbooks often lack a NOS perspective (Gericke & Drechsler, 2006). This study shows that the authors have the ambition to make textbooks that are flexible, timeless and self-sustaining in the hands of the students. This in turn might constrain the possibility to emphasize NOS aspects in general as well as embedded in the content of the textbooks. The teachers’ knowledge and insight in NOS issues then becomes crucial since they are emphasized in the curricula. Also several of the authors explicitly said that they leave these issues for the teacher to cope with in the classroom. “I leave to the teachers to find the cutting edges themselves, which he or she finds interesting, to show off, or use the applications which are topical at the time when the course takes place.” Keeping the authors’ ideas about the use of the textbooks in mind it becomes a crucial implication for teachers to be aware of these expectations when using the textbook in the classroom, and in the same time live up to the curricula’s goals for NOS. The demand of the teachers’ comprehension about content knowledge as well as NOS is extensive and it calls for a use of the textbook that differ from most of the research results found in the literature, which say that the textbooks influence the structure as well as the content of the lessons in high school (DiGisi & Willett, 1995; Juhlin-Svensson, 1995).

However in textbook writing not only the authors’ own ideas and intentions must be considered but also the influence of publishers and editors. The editors gave much feedback on language and layout. However the authors recall only few comments about the content or issues about NOS from the editors. Other important factors determining the outcome of writing textbooks were traditions and expectations of the teachers. In Swedish schools teachers themselves determine which textbook to purchase tending to conserve the structure and the content of the books, since teachers prefer books they can recognize.

References


Argumentative reasoning in peer groups – conceptual issues and epistemological underpinnings
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Background, aims and framework
Argumentation in school science settings is of growing interest, especially the value of argumentation for unpacking the nature of claims and warrants for knowledge (Kelly, 2007, p. 453). In argumentation it is possible for the learner to elaborate and coordinate both cognitive and epistemic goals (Erduran, Osborne & Simon, 2005). It is through argumentation that reasoning and knowing become accessible, both to the learners themselves and to others and then it could enhance the possibilities to perform assessment for learning (Black, Harrison, Lee, Marshall & Wiliam, 2003). The skill to choose from different explanations following a discussion is a discursive practice essential in building scientific knowledge according to Jiménez-Aleixandre and Pereiro-Muñoz (2002). Analysis of argumentation is often done in relation to socio-scientific issues. However, this study’s analysis is towards a specific content, the evolution of life on Earth. It is a topic that could challenge our ontological views, as well as our understanding of evolution. Like other topics it depends on a
number of conceptual issues and their epistemological underpinning. Students’ conceptions about evolution have been investigated thoroughly through individual writings and interviews (Thomas, 2000).

The aim in this study is to investigate conversations in peer group discussions with focus on argumentation patterns towards a substantive content issue; the origin of variation. The aim is to put students’ own wording in the foreground; what students perceive as important conceptual and epistemological issues. The specific research questions are:

- What conceptual issues are articulated and made important by the students?
- How do students justify and support their claims about the origin of variation?

Methods and sample

The empirical data is generated through a group discussion between seventeen-year-old students attending the natural science programme at a Swedish upper secondary school. They are taking part in a teaching-learning sequence about biological evolution. It is their third lesson, the previous two have dealt with genes, inheritance, cell division, mutations and the common descent of life. The context is an ordinary lesson with three group tasks that the students move between. At one station they are supposed to discuss an issue about the origin of variation and new traits (Figure 1). In total there are 29 students divided into seven groups that are videotaped. The teacher asks them to discuss one alternative at a time and if possible come to an agreement. When performing this group discussion the students went to another room, turned on the video camera, discussed, turned the camera off and went to the next task.

Students’ use of arguments are being analysed with the help of Toulmin’s argumentation pattern, TAP (Toulmin, 1958/2003), which is summarised below in Figure 2.

During evolution living organisms have evolved a lot of different traits. The origin of this enormous variation is:

- The individual’s need of the trait
- Random changes in the gene pool
- The species strive to develop
- Need of great variation in order to get balance in nature

Findings

Students’ utterances show a great variety of how they articulate and argue on different conceptual issues. The most frequently discussed issue is whether variation originates from individual needs or from random changes in the gene pool. In order to exemplify the data and analysis (see next page) one short excerpt from a discussion between four students is shown below. In line 114 one student brings up a new example in the discussion; circumcision among Muslims. This is partly done as a reply to an earlier claim by student D that random change is unlikely, articulated as: … if it now is that it originated randomly how come that every animal on the bloody earth has succeeded adapting to its environment.
114 A: you know Muslims and such the boys /../ they cut this epidermis
115 D: foreskin
116 A: yes foreskin from the willie
117 D: pip censor
118 A: and they have done this as long as ever and their children have the entire time got epidermis foreskin I mean
119 D: and it is nothing you need consequently it doesn't develop at all /../ they don't have to do this it has to do with religion
120 A: even if they want to change they will /../ there will never be a change
121 D: because it isn't necessary they don't need it in order to survive
122 C: it is the same thing as ... it is evident that Michel Jackson's kid will be Negro /../ his genes don't change just because he himself gets white

In between these utterances above student D put forward two counter arguments. First in line 119: and ... it is nothing you need consequently it doesn't develop at all /../ because it isn't necessary they don't need it in order to survive and then in line 121: ... they don't have to do this it has to do with religion.

**Conclusion and implications**

The argumentation that student D put forward is an attempt to give more arguments that support the need-rationale, which has strong potential as an explanation among students (Southerland, Abrams, Cummins & Anselmo, 2001). When warrants are scrutinised Toulmin's element **backing** could be applied, although it has to be used with caution, since it often involves interpretation of implicit assumptions. In this case the utterance in line 119 ... they don't need it in order to survive could be seen as drawing on a connection between need and survival; only the needs that are essential for survival are important. Making this remark student D also states a rebuttal, as he points at limitations of where need is applicable. Furthermore it seems that student D rejects the circumcision example because it has to do with religion, meaning cultural evolution and not biological. The argument interposed by C, in turn 122 ... his genes don't change just because he himself gets white is a kind of helping argument. The interpretation of this remark is that it draws on a refusal of the notion that “acquired traits are inherited”. Since this idea is common among students (Jensen & Finley, 1995) the actively articulated refusal is an important utterance.

Many of the disagreements could be traced to putting randomness or need in the foreground when explaining the origin of variation. Partly this is inherent in how the theory of evolution is understood; as one single process or two different processes. For instance it is possible that student D perceives that randomness is the one and only process that is involved in evolution. This insight could be used by the teacher in her/his assessment for learning, e.g. dividing the explanation into one part that is random, the origin of variation and one part that is not random, the selection part.

Students' own wording is accurate most of the time, for example the utterance which settle one group's arguing on the issue of randomness/need ... random changes have occurred, just as it says, but they remained because they were needed. Students' utterances are potential tools for teachers' own “argumentation” that may have more impact, i.e. a language that would touch and influence students more directly without devaluing the scientific clarity and stringency.

**References**


Imaging the nature of physics: a study of visual images in Norwegian physics textbooks
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Background, aims and framework
A range of studies indicates that teachers to a high degree make use of the textbook in their planning and teaching (Nelson, 2006), even in a time where other sources of information are easily available. Hence the textbook is essential in how the nature of a subject is communicated to learners. Textbooks are not merely simplified versions of academic literature in the field, but a re-contextualisation of this knowledge according to the organising principles, prevailing conventions and legitimate ideologies of the school subject (Dimopoulos, Koulaidis & Sklaveniti, 2003). Since physics textbooks are multimodal texts, visual images play a key role in this re-contextualization together with graphs, formulas and the verbal text (Lemke, 1998).

This paper focuses on visual images in Norwegian physics textbooks during a period of six decades. It investigates the various ways in which the images communicate the nature of physics in interplay with other forms of representations, and to what factors the variation can be ascribed.

The research questions are:
• In what ways do visual images in Norwegian physics textbooks communicate the nature of the subject?
• To what degree can variation in the use of images be ascribed to specific time periods, specific authors and school level?

The analysis of images has made use of a conceptual framework from Dimopoulos et al. (2003). Building on the work of Bernstein, Halliday, Kress and van Leeuwen, they provide three dimensions for analysis of visual images:
• Degree of content specialisation (classification); entailing types and function of the image. Types are classified as realistic, hybrids and conventional with increasing use of physics conventions. Functions of images are classified as narrative, classificational, analytical and metaphorical.
• Strength of framing; (negative) degree of involvement of the reader in the social-pedagogical relationship constituted by the image.
• Degree of formality; the degree of abstraction in the image.

The concepts this framework provides are used in constructing the typology of images in the physics textbooks.

Methods and sample
The sample consists of nine physics textbooks used in Norwegian lower and upper secondary schools from 1943 till the present. In two cases two editions of the same textbook were chosen in order to trace changes over time. In addition, two of the books are written by the same authors.

Analysis was undertaken by first categorizing individual images in terms of the dimensions presented. Secondly, five modes of images were constructed based on the categorizations and the images’ function in the text as a whole. Finally, images in the textbooks were coded in terms of these modes, and the relative presence of modes was calculated for each textbook.

The analysis concentrated on the parts of the books dealing with electricity and magnetism, in order to avoid effects of changes in the curriculum’s prescriptions of topics during the time period chosen.

Results
From the analysis, five main modes of communicating the nature of physics were identified in the visual images:

1. Involving the learner in experiments
These images are characterised by being realistic with weak framing, high content specialisation but low formality. The image together with the verbal text presents how a specific experiment is undertaken, and what will happen. The result of the experiment is then used for introduction and discussion of physics concepts or relationships. The subject matter, rather than the experiment itself, often appears as the main aim of the sequence. Nevertheless the text gives the reader the sense of participating in an experimental activity and this way strongly communicates experiments as an important basis for the development of knowledge in physics.
2. Visualising a world of models
A great deal of images in physics textbooks illustrates theoretical models of physical phenomena by visual means. They may be seemingly realistic, but represent conventions in how the world is perceived in physics. Their function is analytical or in some cases classification. This mode of representing physics also includes images that portray ‘inscriptions’ (Latour & Woolgar, 1979) of the world in terms of graphs or diagrams, describing physics phenomena as consistent mathematical patterns.

These two types of images have in common that they demonstrate to the learner that physics is about representing the world in a different way than how it is usually perceived, i.e. by the use of models, and that learning physics means to learn to see the world this way.

3. Showing the actual appearance of objects
This mode of imaging in physics textbooks presents the actual appearance of objects. It embraces realistic images of objects in themselves, free of contexts such as experiments or otherwise. The purpose is to familiarize the learner with specific objects important in physics.

4. Translating between representations
A hybrid of the conventional and realistic images in modes 2 and 3 gives rise to a specific mode of visualisation, creating links between the actual appearance of objects or systems and how features of these are represented in the models used in physics. The role of the image in the text is hence to perform a translation between the two ways of representing the world.

5. Demonstrating relevance and use
These images demonstrate for the learner how the subject matter presented has relevance and is used in society and daily life by presenting objects and systems well known to the learner. They contribute to a reduction in formality and weakening of framing in the text as a whole, but are often independent of the flow of other text.

The typology presented above is used in the final phase of analysis, where each textbook is analysed with respect to possible patterns in modes of imaging. In comparing the results for individual textbooks, some changes over the time span analyzed could be identified, especially with regards to increasing formality in the images. We also see a move from realistic to conventional images, involving a strengthening of the framing, i.e. less involvement of the learner.

With the exception of mathematical formalism, there appear to be no important differences between how images appear in textbooks for levels corresponding to lower and upper secondary school. Identical images were frequently found in books intended for different levels. Reforms in the formal curricula also seem to have had little influence on the kind of images used.

The strongest pattern is found in differences between specific textbooks; they seem to adopt certain modes of visualizing physics, to such a degree that it can be seen as forming specific genres. For example, in one textbook widely used during several decades until the early 1970s, more than half of the images are classified as Involving the learner in experiments, consistently used to introduce new concepts and relationships, and hence highlighting experiments as a basis for knowledge in physics. One of the two leading textbooks used today is dominated by images of the mode Translating between representations, while the other tend to use images as a tool for Visualizing the models of physics. Both books have fewer images of the modes Involving the learner in experiments and Showing the actual appearance of objects than older textbooks, but tend to present more images in the Demonstrating relevance and use mode. Involvement of the learner in the physics presented in textbooks thus seems to have shifted from involvement in experiments to involvement in the sense of recognising physics in everyday surroundings.

It seems reasonable to ascribe the variation between individual textbooks to the preferences of individual authors. However, it was also found that authors of books for different types and levels of schools showed major variation in the pattern of images in their textbooks. Hence authors, or publishers, seem to develop and pursue a specific pattern for each book.

Conclusions and implications
This study has identified a variety of modes of how images in physics textbooks present the subject. Awareness of this variety is important for teachers as well as textbook writers. The increasing formality and the move that has been observed from realistic images and experiments to images that require familiarity with conventions of science is a matter of particular concern. This development may reinforce ‘cascades of inscriptions’ (Roth, Tobin & Shaw, 1997), where the transitions between representations are not transparent to physics newcomers.
A new approach to analysing student argumentation
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Background, aims and framework
The importance of argumentation in science teaching has been stressed by many scholars (Duschl & Osborne, 2002), and there is a growing body of studies focusing on argumentation. So far, a main focus of research on argumentation and controversial issues in science education has been on the process of argument rather than its content, e.g. evaluation of the students skills in constructing arguments and how students form opinions concerning controversial issues (Erduran, Simon & Osborne, 2004). This study aims at doing both: a new approach to analyzing arguments is developed, consisting of an extended version of Mercer’s (1995) way of categorizing talk in small group discussions, combined with a tool for evaluating content of arguments.

The new approach is applied on empirical data from biology role-play debates, to answer the following research questions:
• What is the structure of student argumentation?
• What is the content of student argumentation?
• How does structure relate to content in student argumentation?

Methods and sample
The empirical part of this study is from a context of role-play debates preceded by work in the interactive learning environment Wolves in Norway at viten.no. Wolves in Norway consists of six web-based units and an off-line role-play debate.

Participants were a class of 23 Norwegian students age 14-15. The teacher was the author of this paper. All students worked in pairs, spending four lessons on the web-based activities and two lessons preparing and performing the off-line role-play debates. The debates were video recorded and later transcribed.

The structure of student utterances in the debates were analysed according to an expanded version of Mercer’s (1995) categories for small group discussion (Table 1).

Table 1  Overview of types of talk and the features of each type, based on Mercer (1995). N-students represent nature protection organizations; F-students represent farmer and hunter organizations.

<table>
<thead>
<tr>
<th>Types of talk</th>
<th>Features of talk</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disputational</td>
<td>Claim</td>
<td>Example 1:</td>
</tr>
<tr>
<td></td>
<td>Counterclaim</td>
<td>Student N2: “Actually, as it is nowadays, humans kill more wolves than wolves kill humans.”</td>
</tr>
<tr>
<td></td>
<td>Challenging question</td>
<td>Student F2: “Yes, but it isn’t humans that are threatened by wolves. It is...”</td>
</tr>
<tr>
<td></td>
<td>Avoids answering question*</td>
<td></td>
</tr>
<tr>
<td>Reasoned disputational*</td>
<td>Claim with reason*</td>
<td>Example 2:</td>
</tr>
<tr>
<td></td>
<td>Counterclaim with reason*</td>
<td>Student N4: “They don’t live in captivity, they live on 300 km”*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student F1: “Yes, but they are wandering animals, you said it yourself... They like to wander. It (to be caught) is against their nature.”</td>
</tr>
</tbody>
</table>
The content of student utterances was categorized according to the extent to which they were able to draw on information from Wolves in Norway, or other sources, and use it correctly. The following hierarchy of categories was used: expected-, moderate-, incorrect- and other content (Table 2).

Table 2  Categories for classifying quality of content in student utterances. N-Students represent Nature protection organizations, F-students represent farmer and hunter organizations.

<table>
<thead>
<tr>
<th>Types of content</th>
<th>Features of content</th>
<th>Examples</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other</td>
<td>-Trivial content</td>
<td>Example 1</td>
<td>Illustrates a type of utterance that is classified as out of context, because it is not focused on the original theme.</td>
</tr>
<tr>
<td></td>
<td>-Content on the edges of the original theme</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Non-finished sentences</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-No particular content.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect</td>
<td>-Incorrect use of information from the program</td>
<td>Example 2</td>
<td>Not consistent with the information provided in the Wolves in Norway. Wolves actually have killed humans; both in Norway (200 years ago) and other countries; however, it usually happens only under specific circumstances.</td>
</tr>
<tr>
<td></td>
<td>-Brings in incorrect additional information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>-Partly correct, but inaccurate use of information from the program.</td>
<td>Example 3</td>
<td>Brings in additional information, which is partly correct, i.e. using shepherds is not the only solution to the problem (alternatives are described in Wolves in Norway); and the government might give additional support if farmers test new methods, like using special Polish shepherd dogs.</td>
</tr>
<tr>
<td></td>
<td>-Brings in partly correct additional information.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The content of student utterances was further investigated by analysing the types of arguments that were used in the debates (Table 3).

**Table 3** Classification scheme for types of arguments in student utterances, and numbers of arguments introduced in Wolves in Norway, and arguments introduced in the debates by students.

<table>
<thead>
<tr>
<th>Type of argument</th>
<th>Characteristics of argument</th>
<th>Arguments introduced in Wolves in Norway (arguments introduced by students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological arguments</td>
<td>Those based on biological knowledge about the behaviour and ecology of wolves and other predators, and their influence on other species.</td>
<td>11 (4)</td>
</tr>
<tr>
<td>Economic arguments</td>
<td>Those involving economic gains or losses due to wolves.</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Personal arguments</td>
<td>Those connected to feelings such as fear. Those connected to protection of ones person and livestock. Those giving wolves a non-economical value for people.</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Political arguments</td>
<td>Those connected to laws and international agreements, as well as to consequences of the laws and agreements, i.e. management of wolves.</td>
<td>4 (0)</td>
</tr>
<tr>
<td>Comments</td>
<td>Commenting on other arguments, clarifying questions or similar.</td>
<td></td>
</tr>
</tbody>
</table>

**Results**

Figure 1 visualizes a profile of the discourse in the debates, by showing how the correctness of content in student arguments corresponds to the structure in terms of different types of talk.
Resources for learning science in schools

Figure 2 illustrates the proportion of the various types of arguments used by the students, combined with the degree of correctness of each type.

![Figure 2](image-url)

Figure 2 Types of arguments used in the three debates, and the degree of correctness of each type. 140 arguments are included.

Conclusions and implications
The main contribution of this paper is a methodological approach for analyzing student argumentation in terms of both content and structure. This approach illustrates the correctness of content in different types of talk. Both simple claims and more elaborated argumentation contained correct content. The content analysis showed that the majority of content in student utterances was correct or partly correct, indicating learning gains. Students used biological, personal, political and economic argumentation reflecting the sense of having access to a tool providing information from multiple sources. Furthermore, exploratory talk seems to be associated with correct content.

This study also demonstrates that the new approach to analysing argumentation can be used to analyse all discourse in teaching sequences like debates and discussions. In contrast to other approaches where just selected sequences are analysed, the new approach provides an important overview of what types of talk are used in the whole discourse. Furthermore, whether or not the utterances consist of correct subject content, and what type of subject content that is used. Such information is useful for teachers and science educators in evaluating whether students are able to apply subject content knowledge in settings like debate or discussion. Moreover, the new approach is a tool that may help us considering whether or not to teach explicitly about the construction of arguments and to which extent the teaching aims regarding subject content are reached.

References


Brittiska studier (Driver, 2000; Newton, 1999) visade bl.a. att diskussioner och argumentationer utgjorde en försvinnande liten andel av undervisningen i naturvetenskap och att lärarna ansåg att det är svårt att leda diskussioner. Dels beror detta på att lärarna inte ansåg sig ha tillräcklig erfarenhet av och kunnande i detta, dels på den kunskaps- och vetenskapssyn lärare i naturvetenskap ofta omfattar.

Toulmin’s argument pattern (TAP) (Toulmin, 2003) har använts och utvecklats i flera studier i syfte att studera elevers argumentation och hur den utvecklas. Det är dock sällsynt med redovisningar av detaljer i argumentationerna och hur dessa är uppbyggda. Syftet är att detaljerat beskriva hur elevernas argument är uppbygga för att bättre förstå förutsättningar för lärande i gruppdiskussioner.

**Metoder och urval**


Problemet som eleverna diskuterar är hämtat från den Nationella utvärderingen av grundskolan 2003, ”Bevaras massan då is smälter” (Andersson, Bach, Olander & Zetterqvist, 2005, p. 66). Uppgiften handlar om huruvida massan förändras så att en sluten burk med is kommer att väga mer, mindre eller oförändrad efter att isen har smält.

Frågeställningen behandlades först i grupper om tre eller fyra elever som en av flera uppgifter. En av grupperna filmades. Dagen efter följdes gruppernas bearbetning upp med en diskussion mellan läraren och elever från flera grupper i halvklass. Lektionen filmades.


**Resultat**

Analys av samtalen som rörde uppgiften under de två lektionerna gav tre tydliga ”Patterns of Argumentation”. Tidigt framkom ett mönster med utgångspunkt i att is är lättare än vatten varför burken bör väga mer efter smältning.

**Figur 1**  

**Toulmin Argument Pattern**

- Faktatillstånd
- Belägg
- Skäl
- Tes, påstående
- Villkor
- Styrkemarkör

**D** (Is är lättare än vatten)  
**So Q** (tror att/ borde bli så att)  
**C** (Burken väger mer än 630 gram när isen har smält)

**Since W**

(Is flyter på vatten)

**Figur 2**  

Burken bör väga mer efter att isen har smält.

Under lektion två, när halva klassen diskuterade problemet tillsammans, bad läraren att de olika grupperna skulle presentera sina resonemang. Då framträdde två andra ”patterns of argumentation”. Det ena gick ut på att eftersom is är hårdare och tar mer plats bör burken bli lättare efter att isen har smält.
Figur 3  Burken bör väga mindre efter att isen har smält.

Eleverna som framförde ståndpunkter enligt det tredje mönstret menade att burken har ett lock och att därmed inget har tillförts eller lämnat burken, varför den borde väga lika mycket hela tiden.

Figur 4  Burken bör väga lika mycket efter att isen har smält.

Diskussionen gick vidare och några av eleverna med utgångspunkten att burken blir lättare efter att isen har smält fördjupade sitt argument med ett ‘backing’, nämligen att övriga måste hålla med om att gas är lättare än flytande och att därmed borde flytande vara lättare än gas.

Figur 6  Utvecklad argumentation om varför burken blir lättare efter isen har smält.

Framförallt en pojke stod fast vid att burken väger mer efter att isen har smält. Argumentet att gaser är lättare än flytande stärkte hans ståndpunkt att burken kommer att väga mer. Is flyter på vatten och gaser svävar i luften – således är vatten tyngst, is lättare och vattenånga lättast, vilket innebär att burken väger mer efter att isen har smält.

Figur 7  Fördjupat argument varför burken blir tyngre efter att isen har smält.
Diskussionen gick fram och tillbaka mellan eleverna och läraren gick också in i diskussionen och ställde frågor om materiemängd före och efter smältning. Det visade sig då att eleverna var överens om att mängden materia är lika före och efter smältning. Läraren menade då att saken var klar, vikten ändras inte. En av eleverna gav sig dock inte utan hävdade bestämt att det inte betyder att vikten är densamma.

**Slutsatser och implikationer**

Analysen m.h.a. TAP visar att elevernas olika resonemang var och ett på sitt sätt är logiskt uppbyggda med en struktur som går att beskriva. Eleverna uppfattar, utgående från samma problemställning, olika faktablindställ, framför skillde skäl med belägg för hur faktablindståndet hänger samman med deras eget påstående. Sammantaget pekar de olika TAP på att eleverna har olika föreställningar om vad som händer med **vikten** vid materiatransformationer.


Ett annat skäl kan vara att en del av det som karaktäriserar **Exploratory Talk** (Mercer et al., 2004) saknas. Elevernas uttalanden blev aldrig resurser för vidare resonemang, man lyckades inte överbrinna avståndet mellan de olika föreställningarna.

**References**


Learning science with ICT
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Background, aims and framework

Background
A new national curriculum for Icelandic schools was published in 1999. Both the science and the information and technology education curricula from 1999 made considerable demands on teachers. Science was to be taught through three themes – the nature and function of science, science content (physical, life and earth sciences), and methods and skills. Information and technology education was divided into three subject areas – information studies, creativity and the practical use of knowledge, and design and technology. In addition, guidelines were provided for the development of computer skills.

A recent study in Iceland drew some general conclusions about the kinds of support and structure teachers seem to need in order to make the use of ICT a real option in their teaching (Lárusson, Macdonald & Þórólfsson, 2005). Technical difficulties can hinder the use of ICT in subject-based classes and many teachers need support from teaching advisers, library specialists or computer specialists in order to use ICT in their classroom teaching. Other research indicates that teachers do not adopt ICT unless its use is aligned with their usual teaching practice and that this practice is largely teacher-centred (La Velle, McFarlane & Brawn, 2003). In a study of 25 technology-rich classrooms in five European countries, Smeets and Mooij (2001) drew essentially the same conclusion; that despite more pupil-centred environments, teachers tend to stay firmly in control of them. Osborne and Hennessy (2003) suggest that part of the difficulty with using ICT seems to lie with a national curriculum loaded with science content although new curricula are more likely to encourage the use of ICT with an emphasis on critical and analytical skills (Osborne & Hennessy, 2003).

Aims
During 2005 research was carried out with five science teachers in the urban southwest area of Iceland with support from the IUE Research Fund. The study was designed to:

- consider the conceptions of teaching and learning held by these teachers
- assess the extent and manner in which ICT was used by them in their science teaching.

In the first part the authors found that all five teachers experienced the pressure for coverage as a constraint and they were well aware of their students' different needs and diverse learning styles (Þórólfsson, Macdonald & Lárusson, 2007). The teachers talked about taking the differences of students into account and admitted that the learning context is a crucial factor for learning. They suggested that the system assumes that teaching science is still mostly about transmission of knowledge and the transfer of information from books and other sources of information into student's minds.

The aim of this paper is to report on the second part of the study i.e. to assess the way in which the five teachers were using ICT in their science teaching.

Framework
Research suggests that ICT can be used to strengthen procedural knowledge and that the main forms of ICT which are relevant to school science activity include: tools for data capture, processing and interpretation, multimedia software, information systems, publishing and presentation tools and computer projection technology (La Velle, McFarlane & Brawn, 2003; Osborne & Hennessy, 2003). Using ICT for such purposes calls for a particular view of school science. ICT could reduce both the time and resources constraints in practical work. There is however a need for a learning context in which exploration and testing can occur, for example, simulation and digitally presented data sets, such that students can learn more about the underlying scientific processes.

Newton and Rogers (2003) suggest that ICT tools add value to science lessons in two ways; through the intrinsic properties of ICT, such as time saving or handling data, and through potential learning benefits from the manner in which ICT is used in the classroom. They make a distinction between properties and benefits. Operational skills are needed to exploit the properties of ICT but application skills are needed to exploit the benefits.

Newton and Rogers suggest that use of ICT can be related to pupil-learning modes suggested by Scrimshaw (in Newton and Rogers, 2003) which are in line with constructivist ideas of teaching and learning science. As receivers learners can obtain knowledge or collate and record information. As explorers they explore ideas and external knowledge. As creators they present, report and create their own understandings. To Scrimshaw's roles they add that of reviser where students engage in revision activities or practice activities.
Twining (2002) developed the Computer Practice Framework (CPF) with which it is possible to differentiate ways in which computers are used in teaching situations. The question “For what purpose?” concerns the extent to which the use of the technology is affecting the content and practices of learning. Twining has identified three categories:

- ICT used as support (same content, automated process but essentially unchanged; could be more efficient but does not change the content)
- ICT used for extension (different content and process but neither requires a computer)
- ICT used for transformation (different content or process, both requiring a computer such that either the content or process changes).

In summary, the literature indicates that for effective use of ICT in science the following factors will be important:

- ICT is usually used in alignment with existing pedagogical practice,
- ICT can be used to support the development of procedural knowledge, and
- Teachers need technical and advisory support for using ICT in science teaching.

Furthermore, teachers could find it useful:

- to differentiate between the properties and the benefits of ICT
- to consider the different roles which learners must assume such as revisers, receivers, explorers or creators of knowledge
- to realize that ICT can be used to support, extend or transform learning.

Methods and samples

During 2005 the research team carried out a study on the use of ICT in science teaching, with funding from the IUE Research Fund. Five teachers, three male and two female, participated in the study and were all from the urban southwest. A snowball sample was used in identifying the first three teachers as being “good” science teachers. The other two were known to the researchers as innovative teachers of science. Four teachers were teaching at lower secondary level, and one at middle school level.

Semi-structured interviews lasting about 60 minutes were taken with five teachers in their classrooms, followed later by an observation of a lesson selected by the teacher as being a typical lesson. The interviews focused primarily on the ideas teachers had about learning and teaching in science and their typical practice. The interviews were then transcribed for further analysis. During the observations attention was paid to nature and content of the interactions between teacher and learners. The observation was followed by a short interview to clarify points arising from the earlier interview and the observation.

Results

It appears that the use of ICT by science teachers seemed to be consistent with their ideas about teaching and learning science.

Three of the teachers favoured a student-centred approach to science learning, one a mixed methods approach and one a teacher-centred approach. The way in which ICT was being used is aligned with these approaches. Those who favour a student-centred approach would like to encourage a range of skills; and would like to use ICT in all areas of learning. Simon uses digital film clips to tape presentations for later evaluation and interacts informally with students. Smart board and slide presentations are used by students during presentations. Jacob emphasises discussion periods and allows students good access to him, between lessons and through MSN after school. There is a relaxed atmosphere in the lesson and students are encouraged to use the web to look for information. Olive likes to use a variety of teaching methods, to meet different interests and needs, and prefers to follow the national curriculum rather than books. She uses the computer and the Internet much of the time and students use the Internet, spreadsheets, slide presentations and word processors.

Saga, who adopts a mixed approach, values traditional investigations and is guided by the textbook. She seldom uses demonstrations and follows the curriculum closely. She feels she is not strong in ICT but would like to be stronger. She is reluctant to direct students towards web-based information because so much of it is in English. Students take notes from powerpoint presentations.

Peter who adopts a teacher-centred approach favours direct teaching, built on the text, notes and key concepts. He values a structured approach and uses demonstrations in place of students doing practical work.

Conclusions and implications

The teacher who used ICT the most in science had a strong student-centred approach but also had a strong background in ICT itself. Few of the teachers seemed to use ICT in order to transform learning (cf. Twining, 2002) but some used ICT to support or extend learning.
There is little evidence of ICT being used to develop procedural knowledge in science as suggested by La Velle et al. (2003). Indeed the first results from these five teachers do not indicate the presence of a strong science culture – for example, Simon and Peter appeared to be very different in their approach to the subject of school science.

Follow-up work is needed to look more closely at the conditions which seem to favour the use of ICT in science teaching and learning in Icelandic schools by studying teachers who are known to use ICT in learning and to understand critical points in their personal history of science teaching.

References


A qualitative exploration of teachers use of ‘digital creativity’ technology to re-engage detached learners
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Background, aims and framework
The term ‘digital creativity’ commonly refers to the interface between digital technologies and the ‘creative arts’. This paper takes a broader definition: ‘the imaginative application of computer hardware and software to support learning and learning design across the school curriculum’. The focus of our report is that sub-set of qualitative data from our Becta (British Educational and Communications Technology Agency) funded research that reveals interesting potential in the domain of science education. Following informal research enquiries, this one-year project provided more systematic evidence on the impact of ‘digital creativity’ on pupils’ behaviour, attitude, learning and attendance and on school and teacher practices in using digital resources creatively (Russell & McGuigan, 2008). The target pupils were designated as having ‘behavioural, emotional and social difficulties’ – BESD being a classification indicating additional educational need and defining those young people potentially most disengaged from formal education. Information was gathered from learners posing severe teaching and learning challenges to teachers and education systems, though the issues they raise are of equal relevance to mainstream education. The increasing prevalence of 24/7 multimedia ICT functionality requires that urgent attention be paid to the challenges and opportunities afforded by these resources to the development of engaging science education, the more so in the context of pupils’ declining uptake of science subjects. Some wider implications for planning learning design and assessment in science teaching and learning are also suggested.

Methods and samples
Ten schools distributed across England (five residential, all specialising in the education of BESD pupils) participated in the study between June 2006 and July 2007. One link person was identified in each school which received a donation of hardware and software on the understanding that information about usage and impact would be systematically recorded. Hardware was a MacBook Z0D5 Notebook plus a 30GB iPod, Music keyboard, Canon video camera and still cameras. Software comprised the Apple iLife suite (iMovie, iDVD, Photo Booth, GarageBand, iPhoto, iChat, iWeb, Podcaster) supplemented by ‘ComicLife’ (a picture strip page layout facility) and ‘I Can Animate’ stop-frame animation software plus a ‘.Mac’ account. None of the schools had outstanding prior ICT expertise.

A qualitative ‘development and research’ approach was adopted (van den Akker, 1999). Project innovations were fed back to teachers immediately, in contrast to the more typical ‘arm’s length’ approach. Video-recorded exemplification of prior expertise in digital creativity, developed in a school having exemplary practice, was made available to the school sample.

Project data collection used two group meetings, an on-line forum, email and telephone. Teachers maintained records of the frequency and nature of use of the project’s digital resources and pupils’ views of the impacts. Questionnaires were distributed and structured interviews recorded, supplemented by field notes from school visits. All project forum
communications were recorded and classified. The researchers collected multi-media recordings which were transcribed, edited, and interpreted using systematic qualitative methods including diagnostic commentaries.

**Results**
The evidence confirmed that exposure to 'digital creativity' resulted in:

- some radically innovative teaching strategies that enthused teachers and extended their habitual instructional repertoire
- compelling examples of unprecedented levels of learner motivation and enjoyment, including prolonged engagement of pupils with attention deficit hyperactivity disorder (ADHD) and autistic spectrum disorders (ASD). Pupils' pride in the professional appearance of their multimedia products was striking. Examples of pupils' science work have been edited for dissemination, to illustrate to the teaching profession the potential of digital creativity in science education.

**Example 1.** Learners carried out science investigations which they recorded in picture-strip form, using digital still cameras to photograph the processes and one another as they conducted investigations into dissolving. They stored their images using iPhoto, used ComicLife software to construct picture frames, titles, speech bubbles and text boxes, keying in text to add their commentaries, with thought bubbles adding humour and metacognitive commentary.

**Example 2.** Pupils used digital cameras to record their experiences during a visit to a science interactive centre, photographing themselves and their peers as they interacted with the geological exhibits on display, reviewing their record of the experience on return to school.

**Example 3.** Some younger children made animations on the subject of safety. They constructed sets and models and story-boarded the plots before using stop-motion animation software to produce sound and motion morality tales addressing safety issues.

Some educationally important characteristics of digital creativity are:

- multiple modes of expression are appreciated by pupils, both intrinsically and because they offer alternatives to verbal means: less articulate pupils found new ways to express themselves
- access to multimedia was found to be enjoyable, engaging and motivating as a means of achieving success, resulting in enhanced attention span and productivity
- the hardware and software offered a strong link between pupils' life-worlds and the agendas of the institutions they attended, offering 'street credibility' to learning
- multimedia constructions could be highly personalised - personal ownership linked personal values with the educational goals of the institution
- digital products offered pupils convenient and portable means of sharing and storing records of their knowledge and achievements e.g. to add to their e-portfolios
- learners' development of software expertise – often overtaking their teachers’ – facilitated personal control of and re-engagement with educational goals
- many digital creativity activities required or encouraged collaboration, positive interpersonal behavior and consensus
- products having a professional appearance were rapidly produced by inexpert users, resulting in enhanced pride and self-esteem
- software integration - the movement of files between applications - was found trouble-free and user-friendly by novice users.

**Conclusions and implications**

**Theoretical**

Gibson's ecological theory of perception (Gibson, 1979) assumes that human perception has a functional relation with the environment, the possibilities for action being 'affordances'. Gibson's theory invites the question, 'What novel affordances arise from digital creativity resources?' Our research has identified some novel possibilities for meaning-making in the relations between the equipment provided and users. The pedagogical consequences of digital resources are not intrinsic to those resources: they have to be analysed and understood by educators in order to be applied effectively. Multimedia functionality offers scope to express ideas in a range of representational forms, and the disciplines of both rhetoric and semiotics are likely to provide yet further insights. Wertsch's (1995) concept of 'cultural tools' offers a useful sociological interpretation of 'digital creativity': the resources did not just facilitate what might have occurred anyway. New cultural tools give rise to novel behaviours and outcomes and may be empowering. One striking example of enhanced autonomy was the increase in the control handed over to learners. For example, acknowledging the facility with which pupils learned to operate new software, some teachers were willing to accept pupils playing an active role in training not only their peers, but also members of staff and other adults.
Project teachers were unanimous that an important, exciting and innovative educational resource had been made available to them. The impact on ‘intermediate outcomes’ – motivation, perseverance, collaboration and reflection, were strongly confirmed. Novel multimedia affordances were an undoubted factor in teacher success in adopting innovative procedures. The intention is that the project’s multimedia evidence will be used to make pedagogic strategies known more widely to meet a diverse range of pupil needs, both BESD and mainstream.

The limitations of written modes of knowledge communication have been commented upon (Lemke, 2003); some researchers are currently focused on understanding visual representations as used in textbooks (Knain & Hugo, 2007; Roth, Pozzer-Ardenghi & Han, 2005). The implications of multimodal knowledge representation in science education has been the focus of some attention (Kress, Jewitt, Ogborn & Tsatsarelis, 2001). Our research suggests this area remains fertile for further research activity, both theoretical and for practice.

An immediate need is to consider the possibilities and constraints for learning design and for assessment. For computer-mediated assessment, there are implications for the design of information presentation modes and learner response modes. Currently implicit, but likely to become more pressing as school information management systems develop, are the challenges in managing and storing learner multimedia expressions of their assessed understanding e.g. using learning platforms, e-portfolios and virtual repositories.

References