r(e)flect
The Reflective Teaching Material about Energy, Behaviour and Product Development

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Abstract: r(e)flect is a tangible curriculum kit for students age 10-15 to reflect on energy behaviour and make better informed choices about energy use. Along with web-based material, the kit includes a minicomputer, smart plugs (sensors), and an electricity visualization tool especially designed to be used in the classroom to conduct experiments and measurements, perform project work in product development, and increase the understanding of the kWh concept. The curriculum is closely connected to the new Swedish National curriculum and supplies the teachers with appropriate support for assessment of different skills. The project was initiated in 2011 and a first version of the curriculum was tested and evaluated with students and teachers. The feedback from this trial influenced the second iteration of the kit. The new version will be tested in at least 20 schools during the spring of 2014 and this second phase will continue until 2015. The physical r(e)flect material can be borrowed by teachers free of charge, and the web-based platform is open and accessible to anyone.

1 INTRODUCTION

In Sweden, a new national curriculum including course plans in physics and technology was implemented in 2011. Additionally, a new grading system with clearer criteria was introduced. In physics and technology, the subject content and what should be assessed are clearly stated. Within physics, concepts such as energy and power should be dealt with, students should develop an understanding, but also be able to discuss, debate and reflect upon their own energy use. Within technology, students should get insight into the design and development process and their creative and entrepreneurial abilities should be assessed. (Lgr, 2011) The curriculum further states the importance of increased use of computers, not only to search information, but also as tools for learning.

Traditionally, students experience difficulties understanding the concepts of energy and power (Duit, 2007; Solomon, 1992; Wiser and Amin, 2001). Teaching materials have been developed to support teachers with this problem, both in terms of conceptual understanding, and connections to technology and sustainable development (Hobson, 2007; SEET, 2013; Connecticut Energy Education, 2013). Teaching strategies are often based on an investigative approach where the students have the chance to learn the subject content while they understand the situations where the content has value (Barab and Luheman, 2003). Although teaching materials have been developed and curriculums have changed, evaluations (for example PISA, 2009) show that Swedish students still have difficulties solving problems and applying their knowledge in science. Therefore, there is still a need for educational materials supporting teachers.

Teaching within design and product development has increased over the last few years due to its implementation in the curriculum. However, the research and development of practical teaching materials to assist the teaching and assessment of such topics is still needed. (Ritz and Martin, 2013, p. 391):

> “research needs included determining what knowledge and abilities that designing actually involves, criteria for evaluating novice designs, gaining conceptual knowledge through designing, and teacher trainee conceptions of design”

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The teaching material described in this article, which among other things uses a computerized visualization product for examinations in the classroom and conceptual understanding, is based on successful teaching strategies within the energy field. Additionally, one part of the material focuses on the product development process.

2 THEORETICAL BACKGROUND

According to research in science and technology education, students understand the scientific concepts better when they are related to society and technology issues (Bennett et al., 2003). Course plans have also been developed to involve the contextualization and focus on sustainable development, which requires a change of teaching. Research has shown that an increased degree of exploration in different real contexts means that students increasingly appreciate the subject content (Barab and Luehmann, 2003). By teaching current social issues, such as climate change while teaching the traditional concepts of physics, Space (2007) describes how the concepts become more useful, relevant and interesting to the students. The students start to ask questions about discussions they have heard at home, seen on TV or read about in the newspaper. Space also describes student-centred discussions as successful as they develop an interest in physics concepts that did not exist in earlier education.

Research also shows that students become more engaged by project-based, student-centred and interdisciplinary education that is relevant to real life (Blumenfeld et al., 1996; Barab et al., 2000). Project-based teaching allows the students to work with authentic problems and ask their own relevant questions. This motivates them to find solutions they can explain and argue for (Blumenfeld et al., 1996).

Studies show that visualization in varying shapes makes it easier for students to understand abstract concepts, especially when they can study different phenomena and test hypotheses using visualization tools (Kozma et al., 1996). While working with the visualization tools, students should be given the opportunity to express their own thoughts and allow feedback from others. Additionally, a teacher should be able to follow the thought process of a student throughout the exercise. This should also occur in situations that do not include written or oral presentations (Lehtinen and Repo, 1996). If the visualization provides a common view that explains the problem, for example a screen shot that can be studied and referred to, research shows that such collaboration increases the meaningfulness (Anderson et al., 2000).

The teaching material developed within this project aims at providing the students with a visualization tool to explore and understand, among others, the concepts kilowatt-hour, power and energy, through reality-based examinations. By using the material the problems can be visualized and analysed, measurements can be critically examined, and various alternatives can be compared. According to researchers in science and technology education, students should be given the opportunity to plan and conduct their own investigations, make hypothesizes, search for information, and create models, so they can develop these skills. Also important are debates with peers and teachers, which give students the chance to use their knowledge and strategies to take a position and use well-formulated arguments. (emphasized by for example Linn et al., 2004).

The teaching material further allows the students to discover the process of developing a digital visualization tool. It lets them conduct reality-based design tasks in which they work practically, adopting professional roles. De Vries (2012) claims that project work with reality-based tasks, combined with computer modelling and visualization, works well to integrate the subjects of physics, technology, engineering science, and mathematics, and allows further insights into engineering.

This teaching material is based on the idea that, by starting from their own ideas and in interaction with the digital teaching material, students and teachers can together merge the ideas into coherent chains of thoughts and investigations (characteristics of a successful dialogic teaching, according to Alexander, 2004). The material also provides the students the opportunity to reflect upon their own choices and its consequences, which are important bases for understanding, in particular within technology (Pitt, 2006). The material is also based on the following specific strategies, favourable for learning according to Dylan Wiliam (2007): (1) learning objectives must be clearly defined, understood and shared by everybody, (2) discussions and tasks in the classroom need to show if and how learning in class works, (3) teachers must give students feedback that help them progress, (4) teachers should in different ways use classmates as resources to each other and (5) the teachers need to make students own their own learning, for example by self-evaluation and reflection.

3 MATERIAL DESCRIPTION

The teaching material r(e)flect aims at providing students with increased awareness and tools to reflect upon energy use and related behaviour. It is not a normative material, claiming right and wrong energy behaviour. The long-term goal is rather that students, by using r(e)flect, acquire enough knowledge about energy use and its consequences that they can make better informed choices regarding their own energy-related behaviour.

r(e)flect consists of four different parts, (1) the visualization tool (e)lVis which clarifies the concepts of energy and power and enables real-time experiments, (2) the product development process, (3) reality-based practical exercises and (4) the WattVett challenge that enables self-reflection upon energy behaviour. The new approach of this teaching material is twofold:

1. the ***combination*** of the four parts in the same material (there are other teaching materials focusing on one or two at the time)
2. all parts following the common theme of ***energy*** (where electricity visualization tools are a recurring issue in all four parts)

3.1 r(e)flect Box

The teaching material consists of a website (see Section 3.3.) and a physical material, see Figure 1. The packaging has been given an interesting and exciting design to attract both students and teachers.

Figure 1: Parts of the teaching material r(e)flect are packaged in an interesting and excitingly designed box.

When opening the lid, one finds a mirror with the minicomputer of the electricity visualization tool (see next section) mounted on it. The mirror both symbolizes the self-reflection and ”to look oneself in the eyes”. Apart from the computer-based visualization tool, the physical box also includes material for different activities connected to energy use, concepts used in physics and technology as well as developing skills in presentation and argumentation. The box can be borrowed by teachers free of charge.

3.2 Electricity Visualization Tool (e)lVis

The electricity visualization tool (e)lVis (Figure 2) is the main reason for a physical material. It aims at enabling experiments with electrical appliances from everyday life. It clarifies the concepts of energy and power by real-time representation of electricity use. Furthermore, electricity visualization tools are a common theme throughout the teaching material. In the material, the students can follow the product development process that led to a similar visualization product. The two solutions, built on similar systems of components, are compared. (e)lVis has been designed to stand long-term use in the school environment, while the other product suits workplace applications. This also provides the students with inspiration to their own project work.

(e)lVis is composed of a set of smart plugs (sensors), a minicomputer, and a knob. Although the hardware is made of commercial products, the software was custom developed for this project.

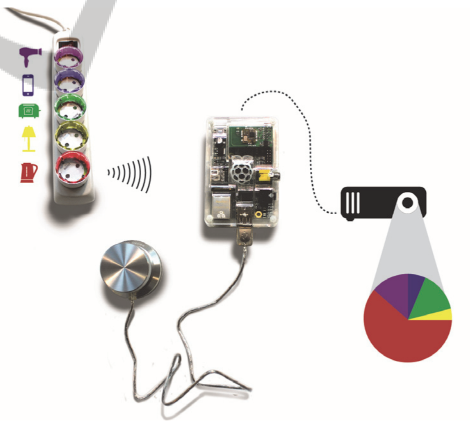

Figure 2: Illustration of a setup with the visualization tool (e)lVis. The tool comprises five smart plugs, a knob and a minicomputer. The minicomputer is connected to the classroom projector to show the measurement and result, i.e. a pie chart where each colour represents a device.

By locating one of the smart plugs between an electrical device and the power outlet the electricity use of appliances can be measured. Each plug is associated with a particular colour. The total amount of energy to be used within the experiment is set with the knob. As the measurement starts the electricity use of each connected device can be followed by its colour in a pie chart. The minicomputer is connected to the classroom projector to show the real-time measurement and pie chart to the students on a screen or the wall. When the full amount of energy has been used, the proportion and number of watt-hours used by each appliance, along with the duration of the complete measurement will be shown, see Figure 2.

3.3 r(e)flect Website

All material included in the box, besides the visualization tool, can be downloaded from the website. This makes r(e)flect widely available to Swedish teachers. The website also provides instructional videos for teachers and engaging informational videos for the students. Throughout the website teachers can find hints, or how to sections, for how the material can be used and linked to the traditional classroom learning. The website is under development, but some screenshots from the current website are shown in Figure 3 and Figure 4.

Figure 3: Front page of r(e)flect website (under development).

Figure 4: Website page showing the four parts of the teaching material (under development).

3.4 WattVett Challenge

An important feature found on the website is the WattVett challenge. It has not yet been implemented, but the concept and how students are supposed to work with it is described in Figure 5.

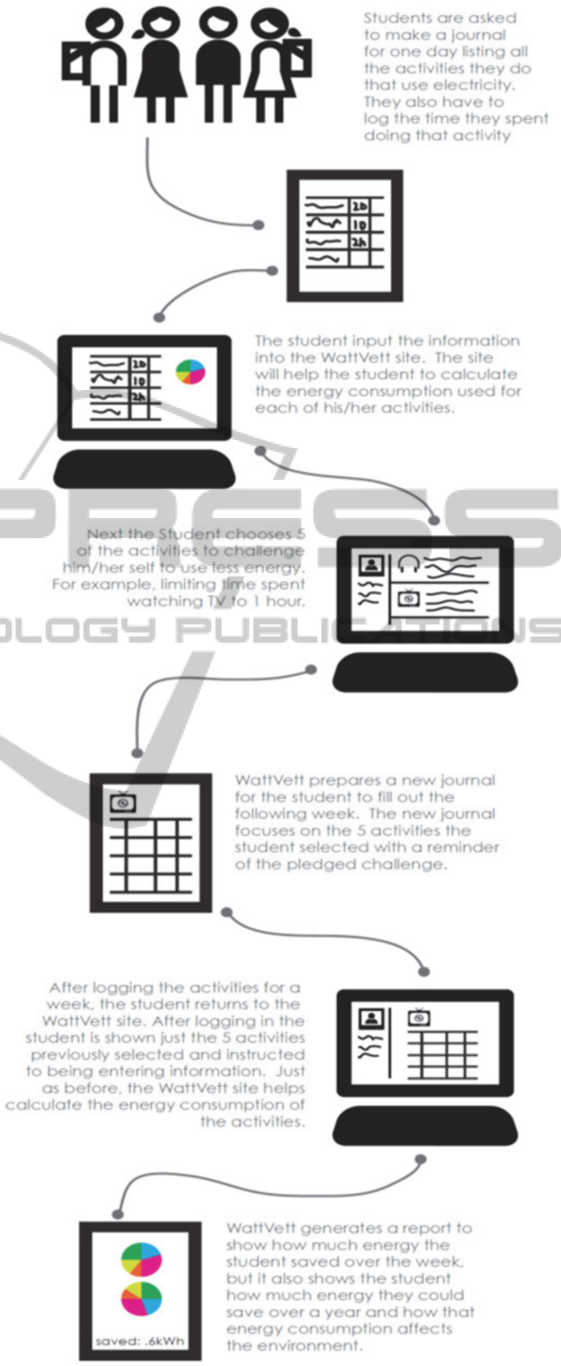

Figure 5: The students' work flow with the WattVett challenge.

In the WattVett challenge, students are invited to challenge themselves or other students and classes. The aim is to encourage self-reflection on the energy behaviour, but also to encourage an energy saving behaviour. Students report their energy use by making an energy diary. Additionally, the self-reporting system can be used to follow up the energy saving potential connected to the teaching material.

4 PRELIMINARY RESULTS

The teaching material was evaluated in two different schools and with totally eight teachers. About 150 students tested different parts of the material. By using short questionnaires, observations and a few interviews we collected feedback and response on specific activities. All eight teachers appreciated the material because it generated interest from the students. Teachers commented in both interviews and questionnaires that the material had a "nice and professional" feel and that it contributes to an entrepreneurial approach, that it helps visualize the students' own electricity usage, and that it can contextualize physics and technology. Teachers appreciate that the activities are linked to curriculum and assessment criteria, and enables cross-curricular elements. All teachers further stress the importance of a teaching material that contains "everything", that clearly describes what needs to be prepared and sourced prior to an activity, e.g. current and relevant links to reports, websites, etc. and reproducible data, forms, etc. These resources are of great value because they are provided within the material.

Students aged 10-15 have used the material in the ordinary physics and technology education. In total, 50 students filled in a feedback questionnaire, another 50 students were observed and six students were interviewed. In all 50 questionnaires the students expressed excitement that "something unusual" happens with a device in the classroom and that they can see the measurement in progress and in real time. Teachers that were interviewed told us that the students can then correlate the measurement to the use of their own electrical appliances.

In the interviews, all eight teachers further expressed appreciation for the tool's measurement of a real situation that can be followed here and now, but also that the students could follow the electricity usage of different products. They can initially guess which one uses the most electricity and then receive a result directly. Subsequent discussion of the concept of power is relevant and highlights the need to consider how long a device is in use.

About 50 of the students in the trial were part of a debate, which proved to be an excellent activity in middle school, even though two teachers expressed concern with the activity in interviews. Observation of the debate did, however, highlight that some basic knowledge must be substantiated. Within the debate students must take a stand for different energy sources and use evidence-based arguments. The debates showed the importance for students to have knowledge about, for example, how electricity is generated by generators and solar applications. The debate also highlighted the importance of the teacher as moderator, guiding the discussion, spreading the word and picking up interesting threads.

About 50 students in lower secondary school tested the "electricity diary" within a homework assignment. The students first measured the electricity use of some "regular" devices of their own choice in the classroom. They reflected upon their everyday life and use of electrical appliances. As homework, they went home and noted their use of electricity during the day, talked to other family members, reflected on the effects on the electricity bills, and estimated the time and measurement of electricity use and costs. In interviews with six students, but also when observing discussions in the classroom, we found that the students, within their reflections, were given opportunities to reflect on aspects they would otherwise never have done.

Moreover, in interviews, two teachers said that the activities contributed to practical lessons for the students, such as realizing that the time aspect plays an important role for the electricity use. The exercises made the concepts power and watt visible to the students, and made them realize that both power and duration has to be taken into account when discussing total electricity use.

In interviews, all eight teachers expressed appreciation for teaching materials with the possibility to make power usage visible to students. They also emphasized the importance of a teaching material that exemplifies idea generation and product development, something that they lacked.

5 FUTURE WORK

We will continue developing the teaching material based on the initial evaluation. Twenty complete teaching kits have already been produced and distributed to schools.

In March 2014, we will let about 10 classes (i.e. around 250 students aged 10-15) and 10 teachers use and evaluate the teaching material. Students' perception of the material will be in demand, and their knowledge of energy will be tested after certain activities. Feedback will be collected through questionnaires, observations and interviews. The teachers' views will be sought through questionnaires. Other students and teachers will also use the material during this period, but they will not be part of the formal evaluation. The evaluation will be based on methods described in Robson (2011).

At the end of the project, in 2015, both the web-based platform and the physical teaching material will be in their final design.

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