Implementation of the CD facilitating reading and writing activities in school science
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Introduction

Reading and writing activities represent well-established approaches to teaching and learning science (Bentley & Watts, 1989; Bransford, Brown & Cocking, 2000). However, learning that centers on reading and writing faces challenges when learners look up information on the Internet, present their ideas with a word processing tool. For instance, reading may entail copying information mechanically from the web page on the clipboard and writing in turn may be reduced to pasting this clip on the document-in-progress or on the discussion platform. In such cases, learners neither process information nor understand the meanings of new concepts not to mention integrating these concepts within their own existing knowledge structure (Suarez & Martin, 2001; Renard, 2000). In this kind of copy-paste process information on the original source is seldom given, which is a serious ethical problem teachers met in their daily work.

In the Finnish PEC project our aim has been to develop activities for school science focusing on reading and writing as processes facilitating learning and discouraging the use of mechanical copy-paste techniques. In this development work we have followed ideas of the design-based-research. The reading and writing activities in the Finnish CD serve as examples of how science teachers can guide their students to read and write and use modern Information and Communication Technologies (ICT) in a manner that leads to efficient learning minimizing moral and ethical problems.

Design-based research approach in CD development

We have used in the development of the activities focusing on reading and writing in science a design-based research approach (DBR) that has been suggested as a solution for the discontinuation between educational research and praxis (Juuti & Lavonen, 2006). It is a general framework for design, development, implementation and evaluation of learning activities and it uses a pragmatic frame. DBR emphasizes three aspects: (a) a design process is essentially iterative starting from the recognition of the need to change praxis, (b) it generates a widely usable artifact, like learning activities or environment, (c) and it provides educational knowledge for more intelligible praxis. In the knowledge acquisition process, the pragmatic viewpoint emphasizes the role of a teacher’s reflected actions as well as the researches’ involvement in the authentic teaching and learning settings (Design-Based Research Collective, 2003; Bell, Hoadley & Linn, 2004).

DBR comprises of the combination of theory development, the prescriptions of successful design processes, and the prescriptions of successful design solutions. The design procedure contains four main phases: 1) needs assessment; 2) theoretical problem analysis and definition of the objectives for a design solution, artifact; 3) design and production of the artifact; and 4) evaluation of the artifact. During the design and production phase, there are typically several cycles: designing of a prototype, evaluation of the prototype in real classroom settings,
revising the objectives based on the evaluation, and re-designing. This phase together with needs assessment can also be called the empirical problem analysis (Edelson, 2002).

During the theoretical problem analysis relevant existing knowledge or answers to identified research problems are searched from the available research literature. In the beginning, designers typically have a tentative strategy by which to manage the problem. One approach to generate these tentative strategies is to use creative problem solving methods. The design team produces the first prototype based on theoretical problem analysis and needs assessment.

Empirical problem analyses deal with designing and evaluating the design solution, artifact. Evaluation may employ multiple methods as Bell et al. (2004) has proposed. The main tool is coordinated communication between teachers (users of the artifact) and researchers (designers). Throughout the communication, researchers help teachers to articulate their experiences gained whilst teaching. Thus, it is not just an individual experience any more, but knowledge about teaching and learning which has been constructed.

The theoretical and empirical problem analyses ensure that the designed activities are easy to integrate into school practice.

**Theoretical problem analysis**

Our theoretical problem analysis was based on relevant research literature on (science) learning in the context of reading and writing (Jonassen & Land, 2000). According to this literature, learning takes more than just transferring information from a web page or some other source into a student’s memory. Rather, learning represents each individual learner’s own personal knowledge construction process which presupposes each learner’s active, goal-oriented and feedback-seeking role.

Meaningful learning engages students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a given topic (Bransford, Brown & Cocking, 2000). The constituents of meaningful learning are the following: activity, intention, contextualization, construction, collaboration, interaction, reflection, and transfer. These serve as development and selection criteria when choosing activities that guide the reading and writing processes.

Activity and intention mean that students take responsibility over their own learning. Thus they set their learning goals and proceed according to the plan to reach the set goal. This process may be facilitated, for example, by guiding students to plan by themselves or in small collaborative groups. Activity may be enhanced also by self-evaluating.

Reflection means that students examine their own learning and develop metacognitive skills to guide and regulate their learning. Metacognitive skills are necessary for planning and evaluating one’s own work. For example, self-evaluating or evaluating in a small group, taking multiple-choice tests, doing exercises and consulting answer keys support developing reflective skills.

Collaboration and interaction mean that students actively take part in group activities and support each other by discussing and sharing knowledge. For example, web-based discussions and peer evaluating texts develop interaction.

Construction and contextualization mean that students combine their earlier knowledge with the new topics to be learnt and thereby tailor information structures that they can comprehend.
Thus learning takes place in situations simulating real-life instances. This in turn presupposes that the learning setting allows for authentic and real-life simulating learning experiences. From the point of view of interestingness, the context in which science ideas are learned, rather than the ideas themselves, has important influence on learning. For instance, when writing it is crucial that students write to prospective readers other than the teacher.

Previous characteristics of learning may be realized through reading and writing activities and the use of ICT. By employing the Internet, students have access to meaningful information by consulting, for example, electronic books, hypertexts and hypermedia. When looking up information in varied sources, students at the same time actively structure the flow of information they encounter into meaningful entities in order to be able to create a report on a given topic. Similarly, this exploration of information in varied sources forces students to evaluate the reliability of both the information and the sources they use.

**Activities supporting reading and writing**

Several types of texts, such as texts in the Internet, can be used as sources of information in learning activities. Once readers understand the meaning of a given text, this text first activates the previous knowledge they have in mind on the subject and then initiates the learning process. This leads into constructing previous knowledge and new information to form a new combination altogether. Previous knowledge affects reading, and it is easier to understand a text that deals with a familiar topic. Moreover, contexts, topics and discussions affect interest and learning. For instance, when discussing, readers can be asked to tell what they already know about the topic and thereby design reading activities that foster learning both concepts and social skills.

Reading represents an active process in which the reader constructs new knowledge by processing the text. At the first time when glancing over a text, the reader creates the ‘first interpretation’ that keeps being reinterpreted on subsequent readings. Both reading and writing involve creating and modifying meanings. For instance, Tynjälä (Tynjälä, 1999) states that learning by reading, creating meanings, may be facilitated by carrying out writing exercises and discussions. Moreover, learning by reading requires distinctive cognitive activities that enable the reader to interact with the text to be read. This in turn is the only way to learn to understand a text even when the contents are very far from the reader’s daily life. The exercises intended to support learning may include the following:

- activating students previous views and knowledge
- comparing students previous views and knowledge with the information featured in the text
- dissecting the views presented in the text
- applying the general principles presented in the text to imaginary practical settings
- voicing critical opinions
- writing a summary.

By memorizing texts students develop into skilled readers and writers of exam answers but these types of skills are rarely needed in further education and at work places. Thus instead on asking students to memorize texts it is more useful to guide them to manage information; critically evaluate information; apply and develop the information available and create new knowledge on the basis of this information.

Learning by reading is affected both by the reader’s strategies and the text to be read. The types of problems that students encounter when reading science texts can be listed as follows (cf. Baker, 1991):
- Texts are abstract having a complicated structure of sentences and are difficult to understand.
- Texts neither encourage readers to identify new things on their own nor guide to problem solving.
- Texts start by explaining concepts and phenomena, established information.
- The number of new terms and concepts (information density) is high and introduced concepts are vaguely explained.
- Introduced concepts do not draw from the previously discussed ones.
- The information structure in texts is blurred.
- Students lack substantial previous knowledge in comparison with what understanding a particular text presupposes. The extent to which students have previous knowledge varies depending on a student.
- Students have several preconceptions on concepts and these conceptions often contradict what the text states.
- Students have never been guided to learning by reading.

During the writing process, the writer develops both as a writer and a human being. Furthermore, expressing one’s ideas, even by just keeping a journal, serves an effective way of testing how convincingly one is able to argue for one’s points. This in turn enables the writer to retrospectively examine the development of the thinking process. In essence, developing one's thinking entails being conscious of one’s thinking process. Writing inextricably involves thinking, which secures it as a cognitive activity. It is common for writing to be a solitary activity by individuals since writing usually demands a high level of concentration. It is also a linguistic activity because the writer has to think about and be careful in selecting grammar structures and vocabulary, especially in interpreting “scientific” ideas. Overall, a teacher should consider that creating a written piece of work is a whole process which involves learners in: gathering ideas - through reading, for example; organizing ideas into sentences and paragraphs; ideas need to be put into a logical order, paragraphs need a main idea and supporting points with a few details; drafting; and editing.

Rivard (1994) has pointed out several factors that are crucial when trying to develop learning by writing. These factors involve, for instance, the requirements set for the student by the writing exercise, the learning atmosphere in class and the students’ metacognitive knowledge and skills. Thus such writing exercises that facilitate learning require the student to reprocess, question, interpret and synthesise issues and principles already learnt. In contrast, traditional exercises only orient students to represent previous information, copy ideas directly from a source, such as, for instance, a course book or a website.

Process writing is greatly facilitated by using modern word processing technology, when ICT facilities are available. It is not only the information sources brought available by using Internet that are important. Crucial is also the possibility to easily change, correct and rewrite, even completely restructure written text during the process. Quite often it is useful first to outline the synopsis of the text and then proceed starting from any piece of content which seems easy to produce. In modern learning environments it is also easy to organize process writing as team work.

Although writing serves as a natural way of creating meanings and viewing the world, writing tasks at school rarely motivate students. We all remember these all too familiar questions “How many pages?”, “Do I have to use full sentences?”, “Are bulleted lists allowed?” This apprehension to learning may also stem from how writing is equated with taking a test. The most crucial issue in bringing about the motivation for writing is to have a recipient or at least an intended recipient and the means to publish the writings. Thus the texts are created for
classmates or other potential readers rather than the teacher. The publication may take the form of a school bulletin, a booklet, or a website. Furthermore, the texts may be displayed in the science class, published on an online learning environment or on the Internet. During the writing process, writers can be supported by giving them the following questions for reflection:

- What else do I know about this issue?
- Shouldn’t I try to explain some concepts?
- Am I proceeding in the right direction?
- Does this take me to the conclusion that I want?
- Have I provided enough evidence to convince an ignorant reader?

**Empirical problem analysis**

Based on the theoretical problem analysis and several discussions with the mentor teachers, supervising science student teachers school practice, prototype activities supporting reading and writing in school science, were done. Altogether, 21 different prototype activities, where reading and writing was essential, were developed (see chapter Teaching and learning activities). Moreover, the mentor teachers organized some teaching experiments based on the prototype activities. A specific questionnaire was used with the aim to clarify what kinds of activities they organized and what kinds of experiences they got. Altogether, 14 mentor teachers returned the questionnaire.

Transcription of the collected data helped to see patterns. This approach led to develop explanations, definitions of criteria for categories in further analysis, as well as more differentiated text, based on the teachers’ answers (Huberman & Miles, 1994).

Altogether 10 mentor teachers organised teaching experiments in which students in small groups used prewritten texts, then drafted, revised, edited, and published a paper together. Mentor teachers emphasised the process of creating writing rather than the end product (cf. White & Arndt, 1991). Some of the themes selected were: the greenhouse effect, radiation in society, kinetic gas theory. Students were required to explain their observations with models, and utilise textbooks, newspapers, electronic databases, and the Internet as information sources. The mentor teachers’ general opinion was that their process-oriented approach helped students to plan their writing, generate ideas, and present a summary of their diverse ideas. Drafting and revising helped students to analyse and structure the information available and discouraged them of just copying the text from written sources or from the Internet using copy-and-paste. The mentor teachers clearly stated how their process-oriented approach activated and motivated students: “Students were enthusiastic”, “They were more interested in science than before”, “All students were active”, and “Even shy students demonstrated creative behaviour”. Based on the products of their work, the mentor teachers thought that it was difficult for students to check the veracity of their information, especially if their source was on the Internet. One mentor teacher described this problem: “The students were eager to find information very quickly. They did not refine their search – they were happy if they found something”. On the other hand, this process-oriented approach helped students avoid copying. Some problems connected with process writing were linked with the heterogeneity of the learning groups: “Students’ ICT skills varied a lot”, “Not all students liked to reread their own work and share it with a small group of students or receive feedback from their peers”.

Almost all mentor teachers answering the questionnaire had directed their students to write short summaries, essays, reports, or poems. Themes included the structure of an atom, a press
review about energy and energy resources, a summary of practical work or an experiment
done at home, and the description of a demonstration in the classroom.

All mentor teachers who answered the questionnaire had asked their students to find
information in different sources, like the Internet and textbooks. The mentor teachers guided
their students through activities typical of reciprocal teaching (Palincsar & Brown, 1984). One
mentor teacher wrote: “I always emphasise activities supporting reading for understanding”.
Students were required to check their understanding of the information available. They did
this by such exercises as generating questions, summarising, graphical network presentations,
and discussions with their peers. The mentor teachers also used these techniques to develop
comprehension skills with expository readings: the mentor teacher and students took turns in
leading a dialogue concerning sections of text.

The mentor teachers were surprised by the influence of the different activities emphasising
reading and writing in learning science. They were happy about the variation in activities:
some were suitable for individuals and some for learning in small groups. It was possible to
combine activities with different learning settings in a unique way. Some of the activities
were creative. For example, upper-secondary school students guided an environmental project
from primary school pupils through an Learning Management System. However, only ten
mentor teachers guided their students through writing activities especially developed in the
project. Some examples of writing activities were: to edit and write a booklet, such as a
radiation-protection guide, or a guide for using an applet, or instructions for performing an
experiment in the school laboratory.

Through the teaching experiments, the mentor teachers noticed that in general, their students
had a rather limited ability to write non-fiction and to understand what they had read. Most of
the mentor teachers were worried about how time-consuming process writing was, and how
many documents they had to read and evaluate. Some were concerned about the copy–and-
paste approach in working with the Internet: “I have to be careful all the time to prevent
copying text directly from the Internet without thinking themselves”. It was important to
guide students to think for themselves, to work with what information was available, and to
check the reliability of the information from different sources.

**Examples of teaching and learning activities emphasising reading and writing in science**

Based on our theoretical and empirical problem analysis a web-page was created (look
http://www.edu.helsinki.fi/pec/FICD/learning_by_reading_and_writing.html). In the web
page both reading and writing are directly connected with learning and thinking. This is why
the Introduction briefly discusses thinking abilities and metacognitive skills. Therefore what
immediately follows deals with learning and sources of information. Moreover, Chapter 2
deals with reading as a process, and Chapter 3 discusses writing as a process. Furthermore,
Chapter 4 introduces various projects focusing on reading and writing, and Chapter 5 features
short exercises aimed at training writing and thinking skills. In the following sub-chapters,
some examples of activities are described.

*Reciprocal reading in groups*

Reciprocal reading aims at activating students to read and study in groups. Students are
instructed to form pairs or small groups. After reading independently for a short while (for
instance, one page), the following activities can be carried out:
- Each member of the group creates an outline on the basis of the read text and then explains the rest of the group this outline (the main points of the text). Afterwards all the outlines are compared with each other and the goal is to focus on the main point of each outline.
- Each member of the group creates a mindmap on the read text and presents it to the rest of the group. The created mindmaps are studied and the aim is to find the essential points in each one.
- Each member of the group generates questions on the basis of the read text and asks the rest of the group these questions. The generated questions and answers are examined, and a couple of questions (1-3) are chosen to be presented jointly in class.
- The read text serves as the basis for organising a joint discussion, role play or debate.

**Process writing**

Writing skills can be developed in science classes as well as in any other subjects’ classes, and process writing represents one way of developing writing skills. Process writing views writing as a process that involves writing, reading one’s own text, having others read the text, receiving feedback and editing the text (White & Arndt, 1991). This writing process may be divided into sub-processes which help in managing writing more easily than when dealing with enormous units of information.

If students have no previous experience from their language classes of process writing, they have to be taught this technique by organising, for instance, short information sessions for this purpose. And even if the students master this technique, it still pays off to remind the students of the basic principles of process writing.

**Journals and blogs**

A basic method to write a story is to connect the story line with some sort of tangible action, and both journals and blogs fulfil this function. Small scale journals can be kept on themes that have been narrowed down. This sort of theme may in turn be connected with science themes, such as, for instance, “saving energy” or “the lifespan of a product”. The following tangible example of a writing task represents the field of energy consumption:

Create a report on the electrical appliances you use over the period of a week and the times you use these appliances. First, take notes, and second, at the end of the week think about the order in which you have to discuss relevant issues in order to give the reader a clear picture of your use of these appliances. Illustrate your points by using graphics, for instance bar diagrams.

**Collaborative story**

The class is divided into groups of four and the students are assigned the labels A, B, C, and D. The task involves creating a story. Student A comes up with the characters (3-6) and their characteristics, whereas student B decides the time and place. Student C in turn invents a story line that involves household electricity chores (the fuse has blown...) and student D thinks of the morale of the story. Each student works independently for ten minutes so that nobody has an idea of what the others have come up with. Finally, everybody shares their ideas and this results in creating the final story and sharing it with the rest of the class.

*An example of use of a web page in reading and writing activities*
The Nuclear Issues Platform (NIP) is an example in an example we used a lot in our reading and writing activities. This is because it presents the subject matter clearly and in a way that young people will find interesting. The NIP can be used with several activities we developed within the PEC project.

Figure 1. The NIP consists of independent sections which can be studied on one’s own or in groups. The sections are Natural radiation, Nuclear power plant, Radiation applications and Nuclear waste storage.

Each section in the NIP comes also with own exercises which a student can complete online. All the exercises can be saved and printed out. The subject matter is made easier to understand through animations and simulations. You will learn about different types of radiation, the operation of a nuclear power plant and the final storage of nuclear waste.

Figure 2. In the ‘Natural radiation’ section a student can learn about the penetration ability of different types of radiation. By dragging an element under the rays with your mouse, you...
can find out whether beta particles pass through humans. The student will also learn more about the characteristics of alpha and beta particles and gamma radiation.

**Teachers’ pre- and in-service activities during the PEC-project**

We have introduced our CD in for science student teachers in Finland through lectures and workshops. The Finnish student teachers have given very positive feedback of the CD. During the student teachers mobility programme we introduced the CD to the mobility student teachers.

We have organised several science teachers’ in-service training courses. The largest in-service course was two day training programme for 180 science teachers. During this specific course teachers become familiar with basics of reading and writing from the point of view of science learning and different techniques how students can be directed to reading and writing activities.

**Two day training programme for 180 science teachers**

Once the Finnish CD was ready, we plan a course and prepare a brochure. A brochure was sent to all upper level comprehensive schools and upper secondary schools in Finland. These efforts alone could not, however, guarantee that teachers would actually use the material.

Organising training for a large number of people can be difficult and expensive in Finland, as distances tend to be long. For example, the distance from Helsinki to the northernmost municipality is more than a 1,000 kilometres. But as we wanted to achieve national awareness of the CD, we decided to invite teachers, who can organize in-service training in their own school and could act as trainers for other teachers.

We select 180 teachers to the two day training and that provided them with the necessary information to carry out training locally.

**Videos demonstrating reading and writing activities**

Many students feel, especially in the beginning of their studies, that “theory” or research based knowledge about teaching and learning a subject is something that they must study but which is not closely related to actual work as a teacher. Typically, the following areas are discussed within “theory” in Finland: teaching and learning mathematics and science, students’ interest and motivation in mathematics and science, national and local curriculum and curriculum planning, teaching methods, ICT in mathematics and science education, evaluation and research methodologies in mathematics and science education research.

Formal teaching about “theory” is easily apart from teaching practice and, therefore, may not be the best ways to combine “theory” and practice together. Therefore, we have linked "theory about learning through reading and writing" to teacher education in several ways. For example during the lectures and workshops our approach is problem oriented that is based on or related to theoretical framework. Here we have used also video clips. These video clips introduce several activities suitable for teaching and learning through reading and writing.

**Reflections**

Based on our theoretical and empirical problem analysis, learning that centers on reading and writing faces new challenges when learners use ICT, like Internet, word processing and LMS.
in their learning activities. Although we have made our work in the framework of science education many of the ideas can be used in other contexts. The activities focusing on reading and writing as processes developed and presented in this paper facilitate learning and discourage the use of copy-paste techniques.

Based on our theoretical problem analysis, there are certain characteristics of reading and writing activities which efficiently support learning. These characteristics were: activity, intention, contextualization, construction, collaboration, interaction, reflection and transfer.

Based on our empirical problem analysis, the influence of the different activities emphasising reading and writing in teaching was surprisingly powerful. They were suitable for both individual learning and small group activities. It was possible to adapt most approaches with an LMS or when conducting scientific investigations. It was also possible to combine a number of previously-developed activities with different learning settings in a creative way. Mentor teachers found ICT useful for co-operative science studies. The main problems were the huge amount of information available on the Internet and the timetable, or how to find enough time for working. We found that the best approaches to discourage the use of mechanical copy-paste techniques are not technical but issues of ethical and moral education.

As a summary, the following properties supporting learning are essential features of recommendable reading and writing activities (Compare Bransford, Brown & Cocking, 2000):

1. Learning is an active process and students thus plan and set goals, study with commitment and evaluate their own learning. On the other hand, students neither master the logical structure of the subject nor recognise their own biased preconceptions, and therefore students’ goal setting needs to be supported and guided. Thus teaching involves using methods and styles that support co-operative planning and evaluating learning.

2. Learning is constructive and encourages students to bring up their previous views and beliefs and thereby construct new knowledge on the basis of this shared information. For example, prior to starting reading or writing, students need to be guided to bring up their prior views on the subject to be dealt with.

3. Learning is collaborative. Learning new concepts presupposes a dialogue both between the teacher and the students and amongst the students (explaining, debating, questioning).

4 Learning is cumulative and students are aided in noticing how a new concept is related to other already familiar concepts (the network of concepts). Students get help in internalising the new concepts and conceptual networks in the given field.

5. New concepts are learned in context. For instance, when using a search machine (Google), students are encouraged to read printed books featuring facts on the concepts to be dealt with. This enables the students to treat the concepts in various contexts and thereby deepen the meanings these concepts acquire. It pays off to keep in mind that the quality of all Internet-based sources need to be checked carefully to ensure that the facts are right (source criticism).

6. Learning develops metacognitive skills. These skills are necessary for planning and evaluating one’s own work. These skills make learning a self-regulatory process in which the student becomes less dependent of the teacher.

References


