Full Length Research Paper

The Use of ICT in Science Education

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This paper attempts to analyze the use of Information and Communication Technology (ICT) in science education from the point of view of learning and interest. Students' interest in science and science learning is analyzed in the context of ICT use in science education and also possible ICT use. Examples of best practices in science education are given. The ideas on how ICT can be integrated into some basic teaching methods are presented. The paper also highlights the potentials of ICT use in science education. The conclusion summarizes the salient features of the paper.

Keywords: ICT, learning, interest, learning management system, integration, teaching method.

INTRODUCTION

Recently, Information and Communication Technology (ICT) has become an important part of most organizations and business out fits (Linn, 2003). Computers started being used in schools in the early 1980s, and several researchers indicated that ICT will be an important integral part of teaching and learning for many generations to come. This is so because modern technology offers many means of improving teaching and learning in the classroom (Rudd et al., 2006).

The use of ICT in education in most countries of the world concentrates on routine type tasks, like sporadic and mechanical information retrieval from the internet. However, teachers and students have high expectations for using computers in their classrooms. This is because ICT can make the teaching and learning of science more interesting, versatile and goal-oriented. It can motivate and activate students and promote co-operation; it can also enhance creativity in learning (Wellington, 2003).

Survey made by Osborne and Hennessy (2003) shows that many science teachers feel themselves insecure to use ICT in education. They argued that ICT cannot be simply added to teaching and learning activities, because the objectives and methods of teaching and learning science will change when ICT is used in education. Instead of following routines with ICT, students should be led to active learning and collaboration. Consequently, it cannot be assumed that the use of ICT transforms science education in all cases for the better. Osborne and Hennessy (2003) further

emphasize the role of the teacher in creating the conditions for ICT use, selecting and evaluating appropriate ICT tools, and designing teaching and learning activities.

Features of effective teaching and learning

According to Bransford, Brown and Cocking (2000), 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 goal for learning. Based on their study, it is possible to present an outline of science learning with a focus on ICT used in learning. Learning represents each individual learner's own personal knowledge construction process which presupposes each learner's active, goal-oriented and feedback-seeking role. The constituents of meaningful learning, according to Bransford and Donovan (2005), are: activity, intention, contextualization, construction, collaboration, interaction, reflection, and transfer. These serve as development and selection criteria when choosing teaching and learning activities emphasizing ICT use.

Activity and *intention* mean that students take responsibility for their own learning. Thus they set, together with a teacher, their learning goals and proceed according to a plan to reach the goals they set. This process may be facilitated, for example by guiding

students to plan by themselves in small co-operative groups. On the other hand, students neither master the logical structure of a subject nor recognize their own biased preconceptions, and therefore their goal setting needs to be supported and guided by the teachers. Thus, activities that support co-operative planning and evaluation are important for learning (Bransford and Donovan, 2005).

Learning could also be enhanced by self-evaluating activities. Bransford et al. (2000) emphasis the role of self-evaluation in science learning. They suggested that a teacher should provide support for students self-evaluating for example by giving them opportunities to test their ideas by building things or making investigations and seeing then whether their preliminary ideas were working. Hence, different kinds of feedback are important to enhance learning.

Reflection means that students examine their own learning and development metacognitive skills to guide and regulate their learning. Metacognitive skills are necessary for planning and evaluating one's own work. These skills also make learning a self-regulatory process in which the student becomes less dependent of the teacher. For example, self-evaluating or evaluation in a small group, taking multiple-choice tests, doing exercise and consulting answer keys support developing reflective and, moreover, metacognitive skills (Rudd, et al., 2006).

Collaboration and interaction mean that students actively take part in group activities and support each other by discussing and sharing knowledge. Learning new concepts presupposes a dialogue between the teacher and the students on the one hand, and amongst the students on the other (explaining, debating, questioning). In addition to face-to-face interaction, ICT offers several possibilities to share ideas through newsgroups, e-mail or through a Learning Management System (LMS) (Bransford and Donovan, 2005).

Construction means that students combine their earlier knowledge with the new topics to be learnt and thereby tailor information structures that they can comprehend. The teacher is therefore expected to encourage 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. Before an investigation or other practical activity students should be encouraged to present his or her prediction or even supposition (Rudd et al., 2006).

Contextualization means that learning takes place in real life situations or in situations simulating real-life instances. This in turn presupposes that the learning setting allows for authentic and real-life learning experiences. For example, when using a search machine (Google), students should be encouraged to look information from different sources. This enables the students to treat the concepts in various contexts and thereby deepen the meanings these concepts acquire. It pays off also to keep in mind that the quality of all internet-based sources need to be checked carefully to ensure that the facts science ideas are learned, rather than the ideas themselves, has important influence on learning. For example, when writing it is crucial that students write to prospective readers other than the teacher (Bransford et al., 2000).

Learning is cumulative and, therefore, students are aided in noticing how a new concept or skill is related to other already familiar concepts or the network of concepts or skills. Learning of science process and ICT skills are similar processes. In both areas there are low level and high level skills. For example, before a student learns to use a LMS he or she should learn to use a word processing and a search machine. Consequently, students should be supported in learning new skills and in internalizing the new concepts and in building conceptual networks in the given field (Rudd et al., 2006).

Previous characteristics of learning actively may be realized through the use of ICT. For example, by employing the internet in the planning phase of the project, students have access to meaningful information of the topic. When looking up information from varied sources, students at the same time actively structure the flow of information they encounter into meaningful entities in order to be able to complete tasks. Similarly, this exploration of information from varied sources forces students to evaluate the reliability of both the information and the sources they use. During science investigations similar procedures can be followed in planning and in repeating the measurements or investigations. In both activities the students can be encouraged to work together and also actively evaluate their activities. Several studies have indicated that information processing, inquiry-based learning, and exploring resources via networks, are beneficial for science education (Linn, 2003).

Students' interest and learning

There are many concepts that can be used to describe motivational aspects of science teaching and learning. Here we shall base our analysis on Self Determination Theory (SDT) and theory of Interest. According to Ryan and Deci (2002), a student's way of thinking has an important role in the process of motivation. Motivated behaviour may be (i) self-determined or (ii) controlled and they involve different reasons for behaving. Self-determined or autonomous behaviour arises freely from one's self. Controlled behaviour, in contrast, means that the behaviour is controlled by some interpersonal or

intrapsychic force, like a curriculum or a task. The motivation styles in SDT are: (i) amotivation (ii) extrinsic motivation and (iii) intrinsic motivation. Intrinsic motivation has positive effects on learning, in particular, to the quality of learning. Intrinsically motivated behaviours are based on the need to feel competent and self-determined (Ryan and Deci, 2000). Extrinsic motivated behaviour is instrumental in nature. Such action is performed for the sake of some expected outcome or extrinsic reward or in order to comply with a demand.

Interest is a content-specific motivational variable. It is approached from two major points of view. One is interest as a characteristic of a person (personal interest) and the other is interest as a psychological state arouses by specific characteristics of the learning environment (situational interest). Personal interest is topic specific, persists over time, develops slowly and tends to have long-lasting effects on a person's knowledge and values (Krapp, 2007). Pre-existing knowledge, personal experiences and emotions are the basis of personal interest. Situational interest is spontaneous, fleeting, and shared among individuals. It is an emotional state that is evoked by something in the immediate environment and it may have only a short-term effect on an individual's knowledge and values. Situational interest is aroused as a function of the interestingness of the topic or an event and is also changeable and partially under the control of the teachers (Krapp, 2007).

According to Ryan et al. (2002) an appropriate context where certain science content or topics are met or teaching and learning activity might have an influence on the quality of emotional experience, which is important for the development of situational interest. Krapp (2007) surveyed Finnish 9th grade students' interest in physics in certain contexts. The most interesting things (especially for girls) were connected with human beings. Therefore, it is important to approach issues through the activities of human beings. Students' out-of-school experiences are different. Boys' experiences are more relative to conventional physics and technical topics whereas those of girls are more closely related to everyday life and health (Krapp, 2007). Thus, human-related experiences during the science lessons are important especially to girls.

Roles of ICT use in science education

Computers have been used in education in many ways from the very beginning of their history. Several ways to analyze the use of computers or ICT in education have been suggested. In the 1980s the use of computers was typically divided to technological and pedagogical use. ICT use was classified based on the type of interaction in two categories: either a student or a computer leads the interactive learning process (Derby and Campbell, 2005). In the 1980s a lot of money in several countries was used for educational software production. This software was used, for example, for training a single skill or learning scientific terms. In the 1990s however, the use of ICT was increasingly analyzed from a pedagogical point of view and ICT use was typically divided into IT assisted learning, tool application and computer science (Newton and Rogers, 2001). In the first category ICT is used as an agent for interaction in many ways. In the second category the computer is a tool. The third category is dedicated for computer science perspectives (Wellington, 2003).

Tool application

Particularly, technology is often used as a set of available tools enabling people to accomplish their tasks in an efficient way. The same applies to ICT, which by its nature can be understood as a large array of hardware and software. Some commonly used "ICT tools" are tool applications: word processing, graphics packages, scanner, digital camera, video, presentation application, databases, spreadsheets, etc (Derby and Campbell, 2005).

In science learning, students can use different tool applications and also learn what needs are met by these application and when and how to use their different features. For example, the following tool applications can be used in science learning: word processing, publications and presentation software, spreadsheets, databases, multimedia, web browsers and e-mail. Word processing software can be used, for example, for organizing ideas, writing home works and project works. Spreadsheets can be used, for example, for analyzing data and modeling. To select the right tool application it is important to understand what types of thinking, learning experiences and experiences of ICT use each ICT to supports (Newton and Rogers, 2001).

A teacher can use tool application in several ways. He or she can present assignments, tests, and other resources for science teaching and learning. Video or LCD projector can be used as a tool in several ways presentations and it can be connected to MBL-tool or a microscope. Tool applications may, however, also be potential drawbacks to this development as it can easily reinforce a didactic style of teaching in which students are the passive receivers and teacher generated ideas and information, albeit, rather more richly illustrated with images. One new interesting tool science teachers have started to use is an interactive whiteboard (white board, SMART board). Whiteboards operate analogously to chalkboards in that they allow markings to temporarily adhere to the surface of the board. The touch-sensitive

display connects computer and digital projector and then computer applications can be controlled directly from the display, write notes in digital ink and save work to share later. Most white boards also have specially designed software that includes a range of useful tools. Advantages of the interactive white board are: documents and software can be accessed from the screen without having to move away to a laptop; it is easy to move between screens to return to earlier work; the drag and drop facility can be used to windows (Selwyn and Facer, 2007).

Computer Assisted Learning (CAL)

Computer-Assisted Learning (CAL) is any interaction between a student and a computer system designed to help the student to learn. CAL includes drills, tutorials, simulations including applets in the internet and virtual-reality environments that can present complex learning situations. CAL includes sophisticated and expensive commercial packages to applications developed by projects in educational institutions or national initiatives to simple solutions development by individuals with no funding or support to tackle a very local problem. Unfortunately, it is not possible to go through all different kind of software which has been developed in the framework of CAL for science education (Bransford and Donovan, 2005).

Computer assisted inquiry

Computer-assisted inquiry is the use of ICT as an aid to collecting information and data from various sources. For example Microcomputer Based Lab (MBL) tools can be used in science inquiry and nature as a source of information. MBL can help in data acquisition and data processing in laboratory. Another example of computer-assisted inquiry is an inquiry where internet or a Web Based Learning Environment (WBLE) is used as a source of information. In both cases, it is important that a student is processing acquired information so that the students learn new knowledge and become familiar with the principles of scientific reasoning (Denby and Campbell, 2005).

In a science inquiry students begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. In partial inquiries, they develop abilities and understanding of selected aspects of the inquiry process. Students might, for instance, describe how they would design an investigation, develop explanations based on scientific information and evidence provided through a classroom activity, or recognize and analyze several alternative

explanations for a natural phenomenon presented in a teacher-led demonstration. Experiences in which students engage in scientific investigations provide the background for developing an understanding of the nature of scientific inquiry, and will also provide a foundation for appreciating the history of science described in this standard. Even though, MBL and other ICT tools do not give explanations but only the evidence or data, students should understand that background knowledge and theories guide the design of investigation, the types of observations students conduct become experiences that shape and modify their background knowledge (Denby and Campbell, 2005).

Distance learning approaches

Distance learning in a natural way has evolved from using regular Computer Mediated Communication (CMC) tools such as email, video conferencing and web pages (Bransford et al., 2000). Thus distance learning solutions are based on a wide range of communication technologies like a newsgroup and a combination of web pages. These separate CMC tools and web pages are combined in a Learning Management Systems (LMS), like Blackboard and Moodle (Krapp, 2007). Currently several teachers are slowly looking for light distance learning tools, like Wiki and blogs, instead of LMSs. For example a teacher can publish interesting problems through a course blog and students can create common Wiki during the science course or as a product of a project. The direction is towards learning networks (Rudd et al., 2006).

All previously mentioned CMS tools can be used in several ways in science education. For example, students from a same school or from different schools can work and communicate together towards common goals in their project. It is also possible that older students supervise younger students' projects through CMC tools. Students can make contact with experts in universities or industry through CMC tools.

Integrating ICT into teaching methods

Teaching methods are typically goal oriented and emphasize social interaction between students and between students and a teacher. The learning strategies are not necessarily the same as the teaching methods used, although there is some overlap, especially when there has been effective co-operative planning or students have studied, for example, in small co-operative group or made concepts maps (Bennett et al., 2004). However, teaching-learning process in science is complex and, therefore, cannot be reduced to well-designed algorithms or a string of sequences of specific

teaching methods (Newton and Rogers, 2001). On the other hand, during a single lesson several different kinds of teaching methods can typically be recognized. We take a look at ICT use from the point of view of teaching methods emphasizing learning in a small group, reading and writing and moreover, practical work (Bennett et al., 2004).

Learning in small groups

Research in science education suggests that communication between students is important for learning. In their systematic review of small-group discussions in science education, Bennett et al. (2004) suggested that successful communication within a group is based on intragroup conflict (diversity of views) and external conflict that a teacher could facilitate. Basic teaching methods are small group discussion, problem-solving, and project work. Further, now and then during the lessons, pupils may learn by oneself solving problems, reading textbook or other references, or writing, for example, essays (Bennett et al. 2004).

Terms like "group work", "teamwork", "co-operative learning", and "collaborative teaching" are used when students work together in groups of two or more with active social interaction. Both face-to-face interaction and mediated interaction using ICT such as e-mail or an LMS can be used. In this kind of learning, five elements are introduced. These elements are typically known in co-operative learning as: positive interdependence of the group members, individual accountability, face-to-face interaction, development of social skills (e.g. communication, trust, leadership, decision-making, and conflict management), and assessment of collaborative efforts by the group members (Bransford et al., 2000).

The internet can be used for data retrieval in learning in a small group. For example the jigsaw method can foster the use of internet and learning in a small group. In the jigsaw classroom the students are first divided into 4-person jigsaw groups. The groups should be diverse in terms of gender and ability. One student is appointed from each group as the leader. Initially, this person should be the most mature student in the group. The lesson is divided into 5-6 segments. Each student is assigned to learn one segment, making sure students have direct access only to their own segment. The students should be given time to read from the internet over their segment at least twice and become familiar with it. There is no need for them to memorize it. In the next stage temporary "expert groups" are formed by having one student from each jigsaw group join other students assigned to the same segment. The students in these expert groups are given time to discuss the main points of their segment and to rehearse the presentations they will make to their jigsaw group. In the

next phase, the students are brought back into their jigsaw groups and asked to present her or his segment to the group. Others in the group are encouraged to ask questions for clarification. The teacher should float from group to group, observing the process. If any group is having trouble (e.g. a member is dominating or disruptive), the teacher should make an appropriate intervention. Eventually, it is best for the group leader to handle this task. Leaders can be trained by whispering an instruction on how to intervene, until the leader gets the hand of it. At the end of the session, a quiz on the material is given so that students quickly come to realize what they learnt (Bennett et al., 2004).

Reading and writing

Several types of texts, such as texts in the internet, can be used as sources of information in science 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 (Bransdord et al., 2000).

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, Selwyn and Facer (2007) 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 (Selwyn and Facer, 2007).

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 grammatical 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, etc. (Rudd et al., 2006).

Practical work

Teacher demonstrations and student practical work have long been accepted as an integral part of teaching and learning science. Experimentations with various teaching methods are essential. From the point of view of the type of activity they can be classified to practical work, teacher demonstrations, class practicals, small group activities, etc (Wellington, 2003).

The importance of the teaching methods in school science, where experiments are essential, is argued for (i) better acquisition of scientific knowledge, (ii) better understanding of the nature of natural sciences, and (iii) the development of working or process skills. Moreover, the student's (iv) attitudes and motivation to study science become more positive and (v) personal growth is enhanced (Wellington, 2003). Nevertheless, researchers do not agree on the significance of experimental methods in physics education. For example, Watson et al. (1995) found out that extra time on practical work had little impact on student understanding. It is claimed that experiments are valuable if both students and teachers have recognized the goals for experiments (Bransford et al., 2000). ICT can be used in several ways with teaching methods emphasizing experiments. Basic tool application like Excel, can be used with experiments.

The potentials of ICT use in science education

The potentials of ICT use in science education according to Newton and Rogers (2001), Osborne and Hennessy (2003), Wellington (2003), Denby and Campbell (2005) can be summarized as follows:

ICT use in science education can
- make learning active, constructive, contextual, co-operative, self-regulated, reflective and cumulative and 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 goal of learning
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- increase interest, motivation and engagement in activities
- provide access to resources (web pages, texts, databases, videos, demonstrations, applets) that are of high quality and relevant to scientific learning,
- help students focusing attention on over-arching issues, increasing salience of underlying abstract concepts,
- enable visualization and manipulation of complex models, 3 dimensional images and movement to enhance understanding of scientific ideas,
- supporting exploration and experimentation by providing immediate visual feedback
- help students to learn to use ICT or increase their digital competence,
- expedite and enhance work production and offering release from laborious manual processes and more time for thinking, discussion and interpretation,
- increase currency and scope of relevant phenomena by linking school science to contemporary science and providing access to experiences not otherwise feasible.

CONCLUSION

Although, we have described here several examples and some of which sounded real success stories, it is difficult to say that certain way of using ICT in science education is more effective than another or even most effective. How effective a single ICT tool (a word processing, a single web page, a data base, a web encyclopedia, educational multimedia, MBL, simulation, etc) for science teaching and learning depends on properties of the tool itself. Effectiveness of an ICT tool also depends on users or local characteristics, such as the pedagogical orientation of the user and his/her beliefs about the suitability of the tool, and support available. External factors such as in-service training and the curriculum and curriculum materials have an influence on the usability of the ICT tool. An "effective use of an ICT tool" is a complex concept and it cannot be analyzed without the knowledge of users of the tool or a context where it is used.

We are living in a very rich digital world. Because of the important and integral role of digital technology in society, science teachers should also reconsider their attitude to the use of ICT and other digital devices. Otherwise science teachers are supporting inequalities in individuals' ICT use or so-called 'digital divide'. Therefore science teachers have a role to play in ensuring that all members of society are able to access the opportunities afforded by ICT use (Selwyn and Facer, 2007).

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