4

Use of ICT in Science Education

By

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Abstract

Use of Information and Communication Technology (ICT) in science education makes science more interesting as it increases society's appetite for result-oriented research and innovation. ICT-driven science education is invaluably important in order to raise students' awareness of different aspects encompassing science and technology in today's society. It addresses the challenges faced by students when pursuing careers in science, technology, engineering and mathematics. Finally, building capacities and developing innovative ways of connecting science to society is a priority through efficient use of ICT since it targets to drastically improve science and technology-literacy in society. Hence, the role of ICT is a sinequanon to Science Education.

Key words: ICT Roles, Science Education, Innovation and Research.

At the time the project Effective use of ICT in Science Education (Eu – ISE)started was the time the Organization for Economic Co-operation and Development (OECD, 2004) published a survey "Completing the foundation for lifelong learning: An OECD survey of upper secondary schools". This survey recognizes that there have been large in-service training programs and large sums have been spent on Information and Communication Technology (ICT) and still the OECD discovered that the use of ICT in schools and disappointing. Adequate guidance and in-service training or professional development of teachers is still a major problem in all OECD countries. The use of ICT in education in most countries 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 science teaching and learning more versatile and goal-oriented, motivate and activate students, and promote co-operation, study in authentic contexts, and creativity in learning (Knezek and Christensen, 2011; Lavonen,

Juuti, Aksela and Meisalo, 2006). Moreover, the infrastructure for using ICT is working well in many areas of society.

The OECD survey and the experiences of science teachers' in-service training, organized by the partners of Eu ISE project, (e.g., Lavonen*et al.* 2006), show that many science teachers feel themselves insecure to use ICT in education. ICT cannot be simply added to teaching and learning activities, because the goals and the way of teaching and learning science will positively change if 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) emphasized the role of the teacher in creating the conditions for ICT use and for selecting and evaluating appropriate ICT tools, and, moreover, in designing teaching and learning activities. Osborne and Hennessy (2003) identified ways in which teachers might make effective use of ICT:

- Ensure that ICT use is appropriate and 'adds value' to learning or "new" goals are activated for teaching and learning science,
- Ensure Prior skills and conceptions of new idea,
- Plan activities or tasks for offering students responsibility, choice and opportunities for active participation,
- Prompt students to think about concepts and relationships,
- Create time for discussion, reasoning, analysis and reflection,
- Focus on goals and tasks including goals dealing with ICT skills,
- Develop students' skills for finding and critically analyzing information.

Student Learning and Interest in Science

1. Features of Effective Teaching and Learning

According to the book "How People learn: Brain, Mind, Experience, and School" (Bransford, Brown and Cocking, 2000), meaningful learning engages students in tackling the topic to be learnt in such a way that it creates meaningful and understandable knowledge structures on the basis of a goal for learning. Based on their ideas, it is possible for us to present an outline of science learning with a focus on ICT use in learning. Learning represents each individual learner's personal knowledge construction process which presupposes each learner's active, goal-oriented and feedback-seeking role. 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 teaching and learning activities emphasizing ICT use.

Activity and intention mean that students take responsibility for their 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 or 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 students' goal setting needs to be supported and guided by the teachers. Thus, activities that support co-operative planning and evaluation are important for learning.

Learning could also be enhanced by self-evaluating activities. Bransford and Donovan (2005) emphasized the role of self-evaluation in science learning. They suggest that a teacher should provide support for students self-evaluation, 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. Different kinds of feedback are important for learning.

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. These skills make learning also a self-regulatory process in which the student becomes less dependent on the teacher. For example, self-evaluation or evaluation in a small group, taking multiple-choice tests, doing exercise and consulting answer keys support developing reflective and, moreover, metacognitive skills.

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 both between the teacher and the students and amongst the students (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).

Construction means that students combine their earlier knowledge with the new topics to be learnt and thereby tailor information structures that they can comprehend. Therefore, the teacher should 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. Respectively, before an investigation or other practical activity, students should be encouraged to present his or her prediction or even supposition.

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 for 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 are reliable (source criticism). From the point of view of interest, the context in which 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.

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 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.

Previous characteristics of learning activity 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 they encounter meaningful entities in order 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).

2. Student Interest and Learning

There are many concepts that can be used to describe motivational aspects of science teaching and learning. Here we base our analysis on Self Determination Theory (SDT) and theory of Interest. According to Ryan and Deci (2002), student's way of thinking has important role in the process of motivation. Motivated behavior may be (i) *self-determined* or (ii) *controlled* and they involve different reasons for behaving. Self-determined or autonomous behavior is one which arises freely from one's self. Controlled behavior, in contrast, means that the behavior is controlled by some interpersonal or intrapsychic force, like a curriculum or a task. The motivation styles in SDT are: (i) *extrinsic motivation* and (ii) *intrinsic motivation.* Intrinsic motivation has positive effects on learning, in particular, to the quality of learning. Intrinsically motivated behaviors are based on the need to feel competent and self-determined (Deci and Ryan, 2000). Extrinsically motivated behavior 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.

Although students primarily produce their motivation, it can be enhanced and learned. In practice, a science teacher can offer optimal challenges and rich sources of motivating stimulations through choosing the learning activities. Therefore, in addition, to previously discussed features of self-determined and controlled behavior of a learner, it is appropriate to analyse also features of a learning activity which could increase the motivation of a learner. This is because self-determined learning occurs when a learning activity itself is considered as interesting, enjoyable or personally important by a learner. From the point of view of the SDT, the motivational features of the learning activity could be classified in five categories:

- *Autonomy – supporting activities/teacher*, through

- Choice of student – centered learning methods like "open ended" inquiry (Wellington, 1998) and other tasks where students have some choices on how to plan or study,
- Collaborative learning activities which support feeling of autonomy,
- Co-planning of the learning activities,
- Use of ICT where students have choices, possibilities for planning and evaluating one's activities and
- Support to the feeling of effectiveness and importance of working;

- *Support to students' feeling of competency*, through

- Choice of inquiry and other tasks, which are possible for the student to solve;
- Choice and use of constructive evaluation methods, like self-assessment, portfolio evaluation, informal discussions, which help students to recognize that they are good at an activity or do the activity well and
- Support for the feeling that the activity has some value or use for the student.

- *Support to students' social relatedness*, through

- Choice to tasks, collaborative learning activities, co-planning and ICT use which help students to feel close to peers and
- Support to the feeling that the students can trust each other and feel themselves close to each other.

- *Support to interest and enjoyment*, through

- Waking up of curiosity by choice of surprise-evoking inquiry and other activities or tasks,
- Enjoyable, funny and interesting activities, like through choice of interesting web pages or simulations,
- Choosing activity which hold attention

- *Science content* (new materials or new knowledge in science) and context (human being, occupations, technology or history).

The ***Self-Determination Theory***(SDT) and Theory of Interest are relative theories. Especially from the point of view of ICT use, similar conclusions can be made based on both theories. For example, it is important to support student autonomy and curiosity for increasing his or her interest or motivation to learn. Both, autonomy and curiosity are possible to support by choosing the activities in a versatile way. ICT use as such can support both feelings. For example, Dori, Barak and Adir (2003) found that ICT-enhanced learning motivates and engages students in learning.

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 analyse use of computers or ICT in education have been suggested. In the 1980s, use of computers was typically divided into 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 (Brownell, 2012). In 1980s, a lot of government money in several countries was used for the educational software production. This software was used, for example, for training a single skill or learning scientific terms. In the 1990s the use of ICT was increasingly analyzed from a pedagogical point of view and ICT use was typically divided into IT assisted learning, tool applications, and computer science (Moursund and Bielefeldt, 2013). 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 (Lavonen, Meisalo, Lattu, Leinonen and Wilusz, 2014).”ICT use in science education is a sinequanon”.ICT is used nowadays in Colleges of education, Polytechnics, Universities and other institutions/industries to conduct Computer-Based Tests(CBTs.). Teachers use ’**power point’** for lecture presentations to the Learners. E-mail, G-mail, Facebook, Instagram, BBM, Xendar ,WhatsApp, Twitter e.t.c are modern day-to-day applications of ICT. Internet is the ICT multimedia platform/environment where all the afore-mentioned social media have successful propagations.

In several situations, not only a computer and software are used in science teaching and learning, but digital equipment is connected to the computer and used. When a digital recording is made, a microphone, digital camera, web cam, computer-controlled microscope or a video camera is connected to the computer. A video or LCD projector is an example of computer projection technology. Microcomputer-Based Laboratory tool is a combination of the Interface, sensor and a software. Moreover, scanners and printers are used as tools in science education. Mobile technology and portable MBL tools offer totally new possibilities for science education.

Tool Applications

Any particular technology is often treated as a set of available tools enabling people to accomplish their tasks in a more efficient way. The same applies to the 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 (Baker, 1991), graphics packages, scanner, digital camera, Excel, power point, printer, video, presentation applications, databases, spreadsheets (Webb, 1993).

In science learning, students can use different tool applications and also learn what needs are met by these applications and when and how to use their different features. For example, 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, wiring home works and project works. Spreadsheet can be used, for example, for analyzing data and modelling. To select the right tool application, it is important to understand what type of thinking, learning experiences and experiences of ICT use each ICT tool supports.

A teacher can use tool application in several way. In addition to previously mentioned, he or she can prepare 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 of 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.

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 developed by individuals with no funding or support to tackle a very local problem. Unfortunately, it is not possible to go through here all different kind of software which has been developed in the framework of CAL for science education.

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. Science inquiry is of course very similar with or without MBL tools. Therefore, a short overview of science inquiry is presented in this journal. 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 also a student – not only a computer – is processing acquired information so that the students learn new knowledge and become familiar with the principles of scientific reasoning (cf. Millar, 2015, p. 15).

Use of ICT in Distance learning/ E-learning.

Electronic mail, newsgroups, chat rooms, and videoconferencing can be intensively used for educational purposes (Madjidi and Hughes, 2014). They offer possibilities for distance/E-learning. Even, Electronic brainstorming and other forms of processes where social interaction is emphasized are of immeasurable importance during Distance learning/ E-learning. Imagine a Lecturer, News Presenter, social Analyst e.t.c who is met with disappointment during Traffic congestion along the road, he or she can use SKYPE as ICT social Medium to deliver his/her lecture/News/speech.

E-mail and mailing lists are the most popular Computer Mediated Communication (CMC) tools extensively used to exchange messages between individuals. A Newsgroup allows users to read and contribute to special-interest" newsgroups". Computer Conferencing (discussion board) enables groups of people to hold discussions by reading and posting text messages on a computer system. The advantage of Mailing list is that messages are archived, and the structure of discussion is also recorded. Computer Conferencing is widely used to support learning. Internet Relay Chat (IRC) allows users to chat 'live' (in real time) using text or audio. NSM messenger and Skype are nowadays well known sophisticated chat tools. Through Videoconferencing, geographically distant people can hold discussions in real time, within which they are able to hear and see each other and share various other types of data. Web-Based Learning Environments(WBLEs) offer inspiring possibilities in science teaching. On-line discussions, information distribution via WBLE are the opportunities for students to learn from one another through exercises, jointly treat the topics to be learnt, evaluate information and learn new things. WBLEs are often used to refer to a combination of face-to-face and online learning.(Brooks, Nolan &Gallangher,2013; Graham, 2014).

Conclusions

Although, we have described here several examples and some of the examples sound 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 database, a web encyclopedia, educational multimedia, MBL, simulation, etc.) is for science teaching and learning depends on properties of the tool itself. Secondly, effectiveness of a ICT tool depends on users or local characteristics, such as the pedagogical orientation of the user and his/her beliefs about the usability of the tool, and support available. Thirdly, external factors such as in-service training and the curriculum materials have an influence to the usability of the ICT tool. An "effective use of ICT tool" is a complex concept and it cannot be analyzed without the knowledge of users of the tool or a context where it 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 use of ICT and other digital devices. Otherwise science teachers are supporting inequalities in individuals' ICT use or e so-called 'digital divide'. Therefore science teachers have a part to play in ensuring that all members of society are able to access the opportunities afforded by ICT use (Selwyn and Facer, 2007).

Based on previous analysis, ICT use in science education can enhance practices and quality of learning in science. The potentials of ICT use in science education can be summarized as follows. Newton and Rogers (2001), Osborne and Hennessy (2003), Wellington (2003), Denby and Campbell (2005) present similar lists of ICT use potentials and present also references where more evidence about the realization of potentials are presented. 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.
- 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 three-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.

ICT also offers teachers opportunities to use tools applications in preparing lessons and teach science.

Recommendations

1. Governments at all levels should provide ICT equipment to schools both in the urban centres and in the rural areas.

2. Workshop, seminars, conferences, symposium, etc should be organized by both the government and educational/professional bodies on the efficient use of ICT gadgets in the schools.
3. Computer education should be made one of the core subjects at all levels of educational institutions i.e primary, secondary and tertiary institutions.
4. Every teacher (especially the science teachers) at all levels must be ICT literate/compliant.
5. Good qualification/certificate in ICT should be one of the prerequisites for admission into higher/tertiary institutions to promote computer literacy.
6. Government should provide enabling environment for internet services for effective teaching and learning of ICT in the schools.

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