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Informatics in Science and Technology Teaching(*)

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Abstract*. A result of the rapid developments in Science and in Technology and of their implications on the technology based societies, the operation of an effective Science and Technology teaching has emerged as one of the most important issues of education. Consequently, there is a need for an overall and, in many aspects, an innovative approach in Science teaching. This approach should refer to the syllabus but also to the teaching strategy and the use of appropriate means, tools and techniques. Within this context, the use of Informatics may be proved an especially useful tool. In this present work I present a review on existing implementations of Informatics in Science and Technology and related perspectives. Specific examples are given and cases of good practice are mentioned.*

Keywords. Science Teaching, Informatics.

1. Introduction

The rapid developments in Science and technology, with their subsequent impacts on society, impose the need of literacy in modern Science and in contemporary Technology, a literacy which should cover the majority, if not all, of the members of Technology Dependent societies. As these advances are new, the contribution from the society (in a Vygotski context) is almost non-existent if not negative (fear of the unknown – alarm for the new'). The only way for a familiarization, moreover for a literacy, on these Science and Technology advances may be achieved only through an effective education and training with innovative approaches to teaching methods, to means, tools, techniques and equipment, to methods of presentation – communication, to the syllabus selection, … . Towards such an effective education and training, the use of New Technologies, especially of Informatics, is a very useful tool. In combination with already existing experience it could produce real breakthroughs in Science and Technology Teaching. The need for a more effective Science and Technology Teaching has lead to an extensive exploitation of the use of Informatics in Education and Training. It seems that, the initial period of concern on and, in many cases, of negation of the use of Informatics to teaching, has evolved in a dominant trend, mostly unsupported, that the use of Informatics will solve problems of education. In all cases it is overlooked the fact that Informatics, as all technologies, may only enhance the results of a good or a poor instruction design. This dominant trend has resulted in an especially flourishing activity. An ever increasing number of relevant works on the use of Informatics in Science and Technology teaching appears in scientific journal, conferences and symposia with the majority of them appearing also on the web [1]. The development of teaching approaches based on the use of Informatics requires expertise on three fields, namely on the specific subject to be taught, on the teaching techniques specific to the subject and on the use of the appropriate modules, H/W and S/W, of Informatics. This expertise is rather unusual to be encountered in a single person. Consequently, the development of teaching approaches based on Informatics is usually effected through teamwork of experts on the three fields. This teamwork performance is better when the experts in one field are also at least literate on the other fields. This may illustrate the recent trend to include courses on pedagogy (instructional design, teaching approaches …) to the undergraduate curricula of technical departments related to Informatics. On the other side, many special S/W applications have been developed facilitating the development of teaching approaches using

Informatics by teachers who may be not experts on Informatics. Also, the curricula for the initial education or training of school teachers include now a considerable section on Informatics. In parallel, there is an extensive program of training of teachers on the use of Informatics in Education [2]. As the tools and processes of Informatics fall within the Science and Technology (S&T) sector it is no surprise that initially the vast majority of Informatics in Education contents referred to S&T issues. In this work, information from a previous presentation [3] is used for a short review of past and current uses of Informatics in Science teaching and cases of good practice which are followed by some perspectives and suggestions.

2. A brief review

The first applications of the Technologies of the information and Communication technologies (ICT) in Education were mainly towards the organization and the management of class and of teaching, e.g. preparation of notes, transparencies, etc for teaching, name lists of students with their marks, formation and adaptation of work- and evaluation- sheets, teaching logbooks, etc. An initial significant application was also the adaptive use of general S/W applications as teaching tools. Examples surviving so far are the use of word processors for language spelling and syntax courses, the use of painting or drawing programs in geometry courses, the use of spreadsheets in mathematics, etc. In Science and Technology Teaching (S&Tt), a very significant development to the acquirement of technical dexterities is still the extensive use of spreadsheets to calculate values and functions, to present graphs and tables, to process experimental measurements, etc. The concern that the 'automation' of the process of experimental measurements (e.g. calculation of mean values, error estimation, axis and scale choice for graphs, …) deprives students of quantitative feeling (order of magnitude of physical quantities, measurement accuracy and size of experimental errors, etc) may be compensated for by manually carrying out similar exercises focused on the process and rules used (e.g. how to choose appropriate scale and axis in a graph, what are the significant factors in error estimations …). However, when such 'automatic' calculations are used in S&Tt, special care should be given to allow the students time for reflection and feedback in order to achieve long term learning.

The use of general purpose S/W has evolved, especially in the area of tertiary education, to the presentation of whole courses in an electronic form. In combination with existing web authoring systems, these may become available through the INTERNET forming a whole sector of electronic books and bookstores. The electronic books very soon were enriched with drawings, pictures, sound, animation, video … and have been evolved to attractive, mostly, multimedia presentations forming the basis for distance e-learning [4], which have the advantage of easy and low cost development with simple means [5]. Combined with their possibility of smooth integration in teaching they can replace other teaching means as the video, the educational TV or the expensive conventional book libraries. Examples of electronic books(tores) are presented at [6] while the actions of the European Union on e-learning are presented at [7]. May be used as a very effective presentation type teaching, useful in training, initial and continuing, and in education aiming at factual knowledge and data. Combined with their low space requirements (a whole encyclopaedia may be contained in a simple mp3 player) and the easiness of production, adaptation and updating of their content it is no worry their extensive use, especially in Technical Vocational Education and training. Also, most of modern repair workshops (i.e. garages, machinery and other complex equipment repair services) operate using electronic manuals and help.

Although innovative as a teaching mode and useful for factual – technical knowledge or for reference purposes, electronic book and multimedia presentations scarcely may be considered to bring fresh ideas to teaching addressing complex cognitive skills. This may be achieved when they are enriched with links and a modular structure to evolve into hypermedia applications. Hypermedia applications which, if properly designed, may operate ('run' or 'executed') either locally, on the computer of the user, or on a server being available to anyone connected to the INTERNET, which, due to its increasing promulgation, becomes another powerful teaching mode with S&T education in the lead. The combination of hypermedia with INTERNET presents many new educational possibilities such as:

- on-line immediate help to teachers, a very useful service especially for isolated schools, without the need for transportation of experts,
- the creation of virtual communities of teachers and other educators where specific subjects may be discussed between colleagues living anywhere,
- the use as a worldwide information data bank,
- the use as a powerful teaching mode.

Some concerns (drawbacks) on the use of widely available information and resources at the INTERNET include:

- In simple INTERNET searches a very large number of data is returned resulting in a need of selecting the relevant information (*'where is the knowledge we have lost in information?' - from 'The Rock' by T.S. Eliot, 1934*). Even using sophisticated search criteria the returns are still many.
- The validity of information is, in many cases, questionable or biased. Note however that any different viewpoint and any criticism on any issue may appear on the INTERNET without, up to now, any effective ban (censorship) impeding it.
- Possibility of a unilateral presentation of information due to two concurrent causes: a/ the attempts from governments to ban information on the INTERNET on reasons of combating terrorism, pornography or otherwise, and, b/ the intelligence of the search engines trying to guess the more probable type of information wanted. This intelligence although mostly useful, may hide the (rare) type of information actually wanted. It is also prone to malicious exploitation; see for example the 'Google bombing'.

An experienced user can minimize or even eliminate these drawbacks leaving all the advantages of hypermedia applications used to education. For Science and Technology education where experimental expertise, modern field advances and examples of good practices are in demand, hypermedias on the INTERNET present good alternatives. Simple such examples may be found in [8].

There are S/W applications addressing specific groups, e.g. educators, or/and specific sectors, e.g. physics, that facilitate the creation of web pages. Most of these applications are of a good quality and low cost while many may be found for free on the INTERNET (just search for 'free software' see also [9]). On the other hand, the technology of web pages has been enriched with active elements that permit the interactive use of hypermedia applications. These elements (e.g. JavaScript©, Java© applets) are lines of computer code that instead of directives on the type and way of presenting information (like e.g. the standard html code) are passed on as commands to the operating system directing it to perform specific tasks, e.g. the execution of another application. Although this possibility has been maliciously exploited for computer cracking, nevertheless it presents many possibilities and, actually, it makes possible high quality teaching approaches, from simple vivid presentations up to complex real self-study teaching applications. The object oriented and modular structure of JavaScript and of Java applets have lead to the creation and availability of specialized modules addressing specific subject areas, e.g. the so called 'physlets', namely Java applets for Physics (see more in [10]). Together with the development of specific Software applications [11] that facilitate the management of providing courses to different groups, they permit realistic distance education e-learning. With these advances in Informatics, an experienced user may develop complete education environments.

Education environment based on Informatics and incorporating the basic principles of constructivism in the form of 'constructionism' [12] has been realized in 1967 by the MIT Artificial Intelligence Laboratory with Seymour Papert as a main actor with the Logo© programming environment. Logo, a LISP like programming language, was used, although on an experimental basis, in teaching young pupils aiming to the development of space understanding and movements (with the 'turtle robot') or to the development of complex cognitive skills (with the 'turtle design' on the display of the computer). In simple teaching implementations with Logo none of the school subjects was, in principle, excluded. However the majority of the simple teaching implementations with Logo addressed Mathematics. The structured programming incorporated to Logo with its recursive modules ('routines' and 'subroutines') permitted to complex teaching presentations (including graphics, sound and animations) often with feedback from the user (learner) mainly in the Science and Technology sector, including visualizations of natural phenomena and, sometimes, virtual experiments a trend peaked after Papert published 'Mindstorms' [13] and facilitated by the proliferation of (personal) computers. Complete libraries of routines were developed (check the INTERNET for 'Microworlds') and distributed with specific Logo implementations addressing school subjects, usually from natural sciences. Another following innovation from MIT Media Lab was LEGO-Logo in which computers with the Logo environments were connected to artefacts made by Lego© bricks and including sensors, lights, and motors. With current advances in Informatics and microelectronics, this has been evolved having now a computer as one of the Lego (or Lego like) bricks making thus possible the construction of autonomous robots. Courses on 'Educational Robotics' are constantly appearing as a potentially very powerful tool for the Science and Technology teaching. Another advance is the construction of small size sensors and other measuring microelectronic devices with low cost and capability of connection (e.g. through USB port) with computers or with a microcomputer as one of their constituents. The term MicroLab or Microcomputer Based Laboratory (MBL) refers to the use of such devices which permit in a Science experiment or observation the measurement of many quantities concurrently and for long times.

3. Perspectives

It seems that the trend described previously will continue in an expanding way. More and more teaching approaches will appear either as autonomous applications or on the web addressing broader groups. This Open Distance Learning type of development may answer problems due to the lack of buildings, equipment, expert teachers and other infrastructure observed especially in Science and Technology at all Education levels, a factor that explains partially the increasing appearance of 'Virtual class'. These are classes in which the teacher(s)-student(s) and the student-student communications are done through computer communication in a synchronous (e.g. videoconference or teleconference) or in an asynchronous way in which the information is prepared, studied and exchanged by the virtual class members at their own convenient time [14]. The development of virtual classes The multimedia capabilities offer the possibility of a multitude of presentations of natural phenomena considered difficult and or outside common experience (see examples in [15]) providing thus the possibility of learning at the level (Bloom's taxonomy) of knowledge and facts. The achievement of learning of complex cognitive and psychomotive skills (e.g. experimentation skills or other practical dexterities) and emotional attitudes requires interactivity with the learner, choice of different learning paths depending on the performance and previous achievements of the learner, time for reflection and active learners' participations. These requirements may be achieved by the appropriate incorporation of active and object oriented programming elements to develop simple simulations or more complex virtual reality environments. Simple simulations appear already in increasing numbers on the web with an expanding range in their contents within a Science and Technology teaching context, e.g.:

- Simple calculations of a table of values and graphs referring to physical quantities in natural phenomena. These usually may be repeated on different parameters ('initial conditions') of the choice of the learner e.g. in order to study the importance of the different factors.
- Real time presentation sequel of the evolution of natural phenomena repeatedly and with varying time scales. This permits comparisons and allows time for reflection.
- Scenario exploitations through the development of representative computer models of natural phenomena. These may be used either to find correlations between observations or to virtual test a scientific theory. This form, initially developed within Science and Technology (see for example the 'Monte Carlo simulations' used in particle physics and in Cosmology) is now used also in Social and Economic sciences e.g. to test an economic theory or to predict the evolution of society characteristics

Virtual reality has been used extensively (but not always effectively) in electronic games and is now entering teaching as education environments with the 'Virtual laboratory' being the most common application (on a more commercial basis electronic representations of known museums 'Virtual museums' have also appeared). In virtual laboratories, the user chooses equipment and devices, arranges them and conducts experiments specifying what quantities is going to process in a virtual computer space within an application simulating the experiment process [16]. Although it remains a simulation representing actual reality, virtual laboratories, if appropriately designed, may become a very effective substitute of actual experimentation [17]. Using special equipment (spectacles, headphones, helmets with sensors …) simulation may be evolved to complete virtual reality situations in which the user (has the feeling that he) lives the intrigues. Although are as yet simulations with multiple pictorial representations, complete virtual reality educational applications will soon appear and, based on past experience, they most probably start from the Science and Technology area.

The advantages of a well designed Virtual Laboratory include:

- Quick familiarization with the experimentation process including the manipulation and presentation of experimental data, with the use of equipment and of the safety rules,
- Reduces the time for preparation and understanding of the basic processes by permitting (virtual) experimentation under different conditions. This especially useful for expensive or for time consuming experiments,
- It reduces the (often high) cost for expensive devices and for operation maintenance, repair and replacement of the equipment.

Virtual Laboratories however do not, in general, advance scientific inquiry skills (unless used in a very specific way) and, as a faithful or not simulation of reality may be not appropriate for small ages where cognitive skills of abstract concepts are still developing (imaging, for example, how a simple electric circuit is represented and how it appears in reality).

4. Commentary

Informatics in Education will continue to spread out as it provides an affordable and efficient tool. For Science and Technology Teaching, Informatics presents the added advantage of facilitating the efficient teaching of issues that are considered difficult either because they are modern, e.g. elements of quantum physics or because they are prone to misunderstandings. Some naïve examples include:

- Simulations for the solar system and of the movements of the Earth in relation to the seasons of the year or the Bohr atomic model. Note that the traditional teaching of the Bohr atomic model is in reference to the solar system ('the atom is a miniature solar system') for which however there is no direct observations (it could be taught equally well that 'the solar system is a magnification of an atom').
- Pictorial representations of quantum atomic orbitals and comparisons with the simplistic Bohr atomic model.
- Use of Monte Carlo simulations for a visionistic representations of the thermal motion [18] a subject very prone to misunderstandings. This technique may be evolved to a full and consistent teaching of Heat within a kinetic theory of particles model context. Such approaches may facilitate the transition from the positivist conclusions of classical physics to the probabilistic (statistical) inferences of quantum physics.

It is increasingly accepted that an effective Science and Technology Education may be achieved by an interdisciplinary teaching approach within a constructionistic context. In this sense, Educational Robotics is especially useful. Pursuing the objective to construct (or assemble) a robot, students may develop complex cognitive and problem solving skills. They are also helped to a better understanding of basic concepts in Physics e.g. through their efforts to chose and manipulate the appropriate sensors or to incorporate movement to the robot. Their creative thinking and scientific interest is excited while they familiarize themselves with modern technology. Such an example of an Educational Robotics course is described in [19].

5. Epilogue

Although the use of Informatics to improve teaching is very feasible, empirical evidence shows that teachers are reluctant to use but prefer to teach within the lines they were taught as students [21. They are reluctant to adapt themselves in new situations and prefer their familiar methods [22]. To my opinion this is the main obstacle towards the proliferation of Informatics in teaching for a more effective Science and Technology Education. To bypass this obstacle, the education and training of the teacher, especially of the Science and Technology teacher, should include an extensive use of Informatics with subjects from modern Science [23] preferring teaching approaches that promote a spirit of research and innovation such as a project type approach or the use of self-made apparatus [24] and connecting Science with everyday observations from everyday life [25].

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7. References and Notes

[1] A simple search with keywords 'Informatics Education Science Technology' produced instantly more the 3million pages. The same search with the keywords in Greek produced more than 200thousand pages [1-Jun-2007].

[2] On a European level see related actions in http://europa.eu/pol/infso/index_en.htm, http://ec.europa.eu/information_society/index_en.htm. For Greece see at http://www.cti.gr/epimorfosi/index2.htm and http://www.pi-schools.gr/epim_tpe/).

[3] P. G. Michaelides, New Technologies in the Didactics of Science (in Greek) in: University of Ioannina, proceedings of the 5th Pan-Hellenic Conference on the Didactics of Science and the Application of New Technologies in Education, University of Ioannina, 15-17 March 2007 http://users.uoi.gr/gtseper/fifth_conf/fifth_praktika.php.

[4] The process actually refers to (self) teaching that, hopefully, will induce learning. A better term would be e-teaching (or e-study).

[5] The Software of a medium personal computer with a simple (video)camera (e.g. a mobile phone) are usually sufficient, on the condition that the user is aware of the capabilities of the software in his-her computer, see more in Antonis Plevrakis, "Creation of Educational Application Systems for Computer Aided Learning " post-graduate degree dissertation at the Department for Primary Education, University of Crete, Rethimno 1993 (in Greek).

[6] http://books.google.com/books?q=e-learning&ots=cc12140-_K&sa=X&oi=print&ct=title [8-June-2007].

[7]http://ec.europa.eu/education/programmes/elearning/index_en.html [8-June-2007].

[8] http://www.clab.edc.uoc.gr/hsci/, http://aplo.eled.auth.gr/, http://www.clab.edc.uoc.gr/aestit/, http://www.eap.gr/, www.cern.ch, (pages Education), http://www.windows.ucar.edu/windows.html, http://www.uky.edu/Projects/Chemcomics/, http://www.webelements.com/webelements/scholar/index.html.

[9] visited on [8-Jun-2007]: http://www.horde.org/, http://www.apache.org/, http://www.fsf.org/. http://www.gnu.org/.

[10] Wolfgang Christian and Mario Belloni, Physlet Physics, 2004, Pearson-Prentice Hall, http://webphysics.davidson.edu/Applets/Applets.html, http://webphysics.davidson.edu/physlet_resources/, http://www.swgc.mun.ca/physics/physlets.html, http://physics.uwstout.edu/physapplets/, or search the INTERNET with the keyword physlets [8-Jun-2007]

[11] http://moodle.org/ [8-Jun-2007].

[12] Papert, S. (1991). Situating Construction. Constructionism, I. Harel & S. Papert (eds.) Norwood, NJ: Ablex Publishing.

[13] Papert, (1980). Mindstorms: children, computers and powerful ideas. N.Y.: Basic Books. Also http://el.media.mit.edu/Logo-foundation/products/books.html#Mindstorms [8-Jun-2007]

[14] Communication through the web is often criticized to enhance alienation in times where societies need closer ties between their members. However communication through the web develops new social skills and, if used in parallel or complementary to the face to face communication may improve socializations and common understanding. A search for 'virtual classes in the INTERNET may provide more information.

[15] http://www.arsakeio.gr/inf_links.htm, http://iskp.csd.auth.gr/projects/sep/, http://www.sch.gr/ (e-material – in Greek), http://public.web.cern.ch/Public/Welcome.html [8-June-2007] or search the INTERNET for 'Science Teaching'.

[16] Virtual laboratories are simulated representations of actual laboratories. In contrast, 'Remote Laboratories' are actual laboratories established in one place with users being able to conduct experiments from another place arranging the experimental equipment and making their observations remotely with the use of computer communications. They might be useful for experiments requiring expensive equipment or posing safety issues, for example radioactive materials.

[17] An example [10-Dec-2007] may be found in http://iskp.csd.auth.gr/projects/sep/ .

[18] G Kalkanis, professor at the University of Athens, private communication.

[19] Simos Anagnostakis, P. G. Michaelides, ‘Laboratory of Educational Robotics’ - An undergraduate course for Primary Education Teacher - Students, HSci 2006 - 3rd International Conference on Hands-on Science, 4 - 9 September, 2006, Braga, Portugal, proceedings published by University of Minho pp.329-335. http://www.hsci.info/hsci2006/index.html.

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