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'Laboratory of Educational Robotics' - An undergraduate course for Primary Education Teacher - Students(*).

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Abstract. *In the Information Technology dependant current societies, the Science and Technology Literacy (STL) is crucial. It is necessary to the prosperity and the further development of the society but, also, it is a prerequisite for the existence of the democratic society of citizens (a democratic right according to UNESCO). Because of the rapid developments in the field, the vast majority of people are not literate in modern Science and Technology (especially in Information Technology). Consequently, the social interaction of the citizens cannot contribute significantly to STL. Only through a systematic education, an adequate STL may be effected. In this aspect, the compulsory education, whose focus is on the preparation of the future citizens, acquires special importance. An effective STL through education presupposes appropriately trained teachers. In this work, we present the design of an undergraduate course to the Department for Primary Education teachers at The University of Crete. The course is titled 'Laboratory of Educational Robotics'. Its syllabus includes the assembly and (simple) programming of different modules towards the construction of a robot performing specified (simple) tasks. The course objectives include the familiarization with the notion of robots and the development of cognitive skills.*

Keywords. Laboratory, robotics, robolab, primary education.

1. Introduction

1. Learning new technologies constitutes a priority in a constantly developing society. The European Union encourages the learning of new technologies aiming at accelerating the formation of a high quality substructure with logical cost, promoting digital training and the universal digital knowledge [1]. On the same lines, UNESCO [2] supports Science and Technology education courses. Science and Technology Literacy may be considered as a right to democracy [3].
2. The rapid advances in Science and Technology do not allow sufficient time for their assimilation and the formation of a corresponding 'social culture'. Consequently:
   - The Science and Technology culture has to be achieved mainly through education,
   - Misconceptions, alternate conceptions and other teaching deficiencies are more frequent in Science and Technology than in the other school subjects where some, at least, of the teaching deficiencies either do not appear or may be counter effected by the society environment [4].
3. Science and Technology Education and Literacy are usually considered within the scope of developing technical and vocational skills and dexterities, implying that the corresponding emphasis is addressed towards the Secondary Education, the Technical Vocational Education and the (initial and continuing) Training. To our opinion however Primary education is more important in view of the following (see also [4]):
   - In all countries, primary education is the longest component of the compulsory education which aims at that personal development which will allow the students (future citizens) their active participation to the society of tomorrow.
   - Students in primary education are at the age where their character and cognitive skill

capabilities are being formed. Misconceptions at this age are difficult to correct later.

- An efficient and correct understanding of the basic concepts in Primary education may heighten considerably the efficiency of the teaching at a later stage.

4. Only an efficient teacher may successfully deal with the hindrances exposed in 2 above. Consequently, an emerging crucial point is the issue of the competence of the Science and Technology School Teacher and, in view of 3 above, of the Primary school teacher.
5. There are numerous studies on the characteristics of an efficient teacher [5]. Although most studies are dealing with a particular parameter i.e. the subject matter knowledge, the teaching approaches adopted, their communication skill with the students, etc. it seems that it is the total profile of the teacher that matters and not the predominance of a single characteristic [6]. However, in view of 1 and 2 above, the knowledge of the subject matter and the teaching approaches adopted are of special importance for the Science and Technology school teacher.
6. Another aspect of the teachers' subject matter knowledge on Science and Technology is what can be considered as a good and sound knowledge. The specialists education or training, although it might help, it does not offer a solution, especially for the Science and Technology teacher., presenting the following disadvantages:

- Due to the rapid advances any education or initial training, however good it would be, it will soon be outdated.
- Training actions necessary to keep the teachers' knowledge in pace with the advances of the field, are limited by the constraints of time, of cost and of the lack of appropriate trainers. The same is true (perhaps to a lesser extent) for the initial education or training.
- Specialist's training is impossible for the primary school teacher (who teaches all school subjects). To some extent this is also true for the secondary school teacher when he (she) assumes the responsibility to teach a subject he (she) is not a graduate of.
- There is always the problem to transform the (scientific) knowledge that the Science and Technology teacher posses to successful teaching actions. This is a serious concern for the modern topics of Science and Technology where there is little previous experience if any at all. For the same reason, teaching experience cannot be expected to improve with time, if not accompanied by other measures.

7. Another characteristic to be considered for the Science and Technology school teacher is the general lack of technical support observed in many schools especially in rural areas and in primary education. Consequentially the Science and technology teacher should be able to maintain, repair or, even, construct the equipment and instruments that are necessary to Science and Technology teaching.
8. In many cases with modern Science and Technology subjects, especially in Informatics, (some) students, quite often, have more skills and, even, (technical) knowledge in the use of computers than their teachers. This upsets the traditional school equilibrium and needs special attention.
9. The background of Primary education teachers is oriented towards humanities. Many of them have a negative attitude towards Science and Technology. Consequently:

- Special actions should be taken in order to develop their self esteem and a positive attitude, prerequisites for an efficient training in Science and Technology teaching.
- In primary schools there is, in general, a culture towards humanities which may improve the efficiency of teaching in humanities, e.g. through informal peer discussions with fellow teachers. Such culture for Science and Technology is, in general, missing from primary education and from many secondary education schools.

10. The education or initial training of teachers in Science and Technology subjects is done by experts in the field. Although they (mostly) deliver a scientifically valid teaching, they are inclined towards the teaching of factual knowledge (i.e. data, procedures, techniques …) and consequently:

- The Science and Technology subjects are considered as difficult subjects [7] because of the extensive use of higher Mathematics.
- The problem to transform the (scientific) knowledge that the Science and Technology teacher posses to successful teaching actions still remains.

11. The education and the subsequent training of the Science and Technology teacher falls traditionally along two extreme lines:

- Training focused to the curriculum in force. It is based to specific teaching approaches,

e.g. through the study of 'model teachings' of specific issues from the school curriculum. It has the advantage of a 'rapid focused' training. Its shortage is that skills to adapt the teaching (e.g. to changes to school curriculum, to the specific class conditions …) are not developed directly.
- Specialist's education based to sound training in pedagogy (general and focused to specific subjects), psychology (of the learner) and subject matter. Its characteristic is that, in principle, the teacher has learned the skills to adapt his (her) teaching to the actual classroom conditions. Empirical evidence however is controversial [8]. When this form is adopted the curriculum combines subject matter and its didactic in interdisciplinary studies.

2. Training for the S & T teacher

The issues raised previously imply that the education and the subsequent training of the Science and Technology teacher should be examined on a different approach within the following axis:

1. Subject matter knowledge should not be factual (i.e. based on data, procedures, techniques, mathematical manipulation …). Instead it should be based on basic principles and methodology (e.g. conceptual Physics) with a sound understanding on the possibilities and implications of the Science and Technology advances. Detailed teaching on specific topics should be exceptional and only if supporting the previous aim. On simple words it should be on know how rather than on techniques.
2. The issues discussed under the teachers' subject matter knowledge should be appropriate for the previous aim (teachers' development). The issues should, also, be in a form to be used in school with little, if any, adaptation. Polymorphic teaching is a relevant choice [9].
3. The teaching approach adopted for teachers' education should be appropriate for the objectives exposed in 1 and 2 above. It should also serve as an apprentice practice towards teachers self training on the subject. Project assignments, in which inquiry and problem solving are encompassed seems an obvious choice. When mastered by teachers and used in schools may provide a solution for the teaching of new (and possibly unknown to the teachers) subjects. This type of teaching in schools permits the self training of the teacher and eliminates the possible drawback of the students knowing more than their teacher as was mentioned earlier (Introduction point 8).
4. In this inquiry, the use of digital information as the one available on the INTERNET may prove as a valuable resort.

3. Course description

The principles described earlier have been used successfully in implementing several actions for the education or the training of the Science and Technology teacher in the Department for Primary Education of The University of Crete (see for example [10], [11], and [12]). We present here the design (within the context designed in the previous section) of another course on Science and Technology planned as an undergraduate course in the Department for Primary Education of The University of Crete.

1. The course title is 'Laboratory of Educational Robotics'. Its main objectives are:

- The understanding of the basic concepts of robots [13],
- Familiarization with robot programming,
- Apprehension of the possibilities and limitations of robots.
- Development of problem solving skills [14].

2. Reason for the choice of a course in robotics are (in brief):

- Robots and robot programming, although mostly unnoticed, are already being used in everyday applications (mobile phones' features, property surveillance mechanisms, electric kitchens and laundries, video and TV tuners, car engines …).
- They present an appropriate environment for exploitation by the students (and the teacher – students) towards the development of complex cognitive skills. In fact they may be considered as the evolution of the LOGO environment [15] introduced in early '70s by Papert [16].
- They provide a good example of modern technology providing also support for the development of construction skills. Teachers and students have the opportunity to familiarize themselves with new methods and materials and with the functional use of technology that will allow them to look deeper into in the (manipulation of the) natural world.

- Educational Robotics constitutes a contemporary educational environment where the user (student) is in the position to compose and guide a robot with the help of a simple optical programming language. In this sense, educational robotics is closely related to problem solving. It may also promote cooperative learning through the assignment of common projects to groups of students.

3. The LEGO™ Mindstorms for schools [17] was chosen as the laboratory environment for this course because:
- It promotes analysis and synthesis skills.
- It is a natural extension into modern technology of the bricks construction kits most children are familiar with.
- The programming language it uses is rather simple with a graphic interface eliminating thus the drawback of learning a programming language [18].
- It incorporates the constructionism philosophy of Papert [16], [19].
- It has a wide range of support for the teachers.

4. The teaching will be through project assignments in groups of two to three persons (see point 3 in section **2. Training for the S & T teacher**.
5. The syllabus of the course is presented in **Table I – A Summary of the Syllabus**. It is divided in two parts with different teaching strategies. During the 1st part students are guided to know the material and its functionality use the equipment and software autonomously. They are also guided to assemble and programme simple constructions. During the 2nd part students are asked to assemble and construct by themselves (in groups of two to three persons) a robot of their choice. During this part the guidance is minimal and initiated by specific (technical) questions by the students.
6. Specific aims during the 1st part include:
- Using and understanding technology,
- Foreseeing technical difficulties,
- Recognizing necessary fundamental concepts,
- Defining technology practices in educational system,
- Using knowledge and understanding of IT (from other courses) to design information systems, and to evaluate and suggest improvements to existing systems,
- Investigate problems by modelling, measuring, controlling and constructing procedures
- Consider the limitations of the tools and information sources, and of the results they provide, and comparing their effectiveness and efficiency with other methods of working
- Discuss some of the social, economic, ethical and moral issues raised
- Using a system that responds to data from sensors and understanding feedback

7. Specific aims during the 2nd part include:
- Using equipment and software to measure and record physical variables
- Exploring a given model with a number of variables and creating models of their own to detect patterns and relationships
- Modifying the rules and data of a model, and predicting the effects of such changes
- Evaluating a complete model by comparing its behaviour with data gathered from a range of sources.

8. Students have to keep a portfolio with completed working sheets and notes on their work. Two evaluation activities are also included in the activity packet.

4. Commentary

Robotics is usually considered as a subject for engineers. Educational robotics has been used, rather successfully, with school students [20], [21]. As far as we know it is the first time planned as normal course for primary teachers' education. A test teaching made 3 semesters ago was very encouraging and lead us to the design of this course. However, some limitations were also located, including:

- For a teaching to large groups of teacher – students multiple sets are required increasing the cost of materials for purchase and maintenance.
- The multitude of specific small parts accessories increases the house keeping load.
- The support material (documentation, web pages …) is in English posing a further obstacle to non English speaking students.
- The course is designed to maximize the development of complex cognitive skills within a constructionism approach. This implies that the student has to devote time to retrospect and think especially during the 2nd part where the student should also take initiatives. These requirements imply high degree of self discipline not observed to all the students.
- Continuous formative assessment of the course is necessary.

Table I – A Summary of the Syllabus

1st PART		
1st week	Introduction, Groups	*9 introductory activities for students related to Robotics concepts. The introduction to programming and algorithmic logic is done with the following steps*
2nd week	*Know the material and software*	
3rd week	*Know the material and software*	• ***pre-programmed robot,*** *the objective is the familiarization with the idea that a series of commands leads to specific actions and vice versa, the appreciation that the action sequence can be materialized by a sequence of commands.* • ***Programming robot,*** *approach with the "logical suites" as a sequence of simple running (executing) steps.* • ***Smart robot,*** *they familiarized with the principles of programming and the control conditions*
4th week	First guided project (car)	*Each one of the guided projects are divided in four levels* *Level 1: Introduction to Robotics* *Level 2: Starting Programming* *Level 3: Further Programming* *Level 4: Structuring compound programs*
5th week	Second guided project (My Home)	
6th week	Third guided project (Bug)	
7th week	Forth guided project (Gadget)	
2o PART		
8th- 9th week	Independent Project 1	*Two long length cooperative learning activities*
10th - 11th week	Independent Project 2	
12th week	Post-test	*Final check*
13th week		*Projects Presentation*

5. Notes and References

[1] See for example the actions and programs in http://ec.europa.eu/education/index_en.html

[2] www.unesco.org.

[3] In Democracy the citizens, acting on their own capacities and not as followers of a "gifted leader" (as sheep under the herdsman), are supposed to participate actively to the decisions taken. As these decisions are increasingly dependent upon Science and Technology developments, the active citizen's participation implies that he (she) not only should be Science and Technology literate but also that he (she) must have cognitive skills permitting decisions on incomplete knowledge, i.e. also in areas he (she) is not an expert. Formation of models develops such skills and is (or should be) an integral part of Science teaching. Within this context the effective Science and Technology education may be considered as a "democratic right", a right to democracy. Otherwise, science will be mixed with religion as in the Dark middle ages or in some places (for example contemporary USA – see http://www.ncseweb.org/ (visited on June 22, 2006) where Science education, especially the theory of evolution became a legal matter competing with religious doctrine).

[4] P. G. Michaelides, '*Training of the IT Primary School Teacher*', 5th Pan-Hellenic Conference with International Participation on the 'Didactics of Mathematics and Informatics in Education, University of Thessaloniki, 12-14 October 2001 (in Greek).

[5] See for example in 'Advances in Research on Teaching', Vol. 2 • 1991 'Teacher's Knowledge of Subject Matter as it relates to their Teaching Practice', edited by Jere Brophy, JAI Press Inc.

[6]  In a previous study, John, a middle school student described the good teachers as the one who: *knows and can teach the subject, answers the questions even the next time, do not say rubbish, learn with the students and not pretending knowing everything, in summary children should learn.*

[7] Krystallia Halkia, 'Difficulties in Transforming the Knowledge of Science into School Knowledge', pp. 76-82, of Vol. II of the proceedings of the University of Cyprus, '1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens', Paralimni-Cyprus 29/4-2/5 2001.

[8] For the case of Mathematics see: Deborah Loewenberg Ball, '*Research on Teaching mathematics: Making Subject-Matter Knowledge part of the equation*', in 'Advances in Research on Teaching', Vol. 2 • 1991 'Teacher's Knowledge of Subject Matter as it relates to their Teaching Practice', edited by Jere Brophy, JAI Press Inc. (pp 3-).

[9] Polymorphic teaching in Science and Technology includes a common psychomotive activity (e.g. constructions, measurements, experimentation ...) which consequently is morphed into different education levels depending on the (previous) cognitive attainment and/or the mentality of the students. It resembles multilevel teaching (i.e. teaching pursuing more than one sectors and levels of learning). The need for polymorphic practice teaching arises usually in the training of teachers to the subjects they are going to teach in school where there is a requirement of teaching in an advanced level for the teachers themselves and teaching in a level more accessible for the pupils. See more in P. G. Michaelides, "Polymorphic Practice in Science", pp 399-405 of the proceedings of the 1st Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Thessaloniki, Thessaloniki May 29-31, 1998 (in Greek).

[10] P. G. Michaelides, '*Introduction to Informatics; A course for students of Departments for Education*', proceeding of International on the Didactics of Mathematics and Informatics in Education, University of Ioannina and Greek Mathematical Society, Ioannina 20-24 October 1993 (in Greek). It describes an introductory course on the use of Informatics to Education.

[11] Athanasia Margetousaki, P. G. Michaelides, '*Affordable and Efficient Science Teacher In-Service Training*', paper to be presented at the HSci 2006 - 3rd International Conference on Hands-on Science, 4th - 9th September, 2006, Braga, Portugal, proceedings published by University of Minho.

[12] Tsigris M. The didactics of Science through polymorphic self-made experimental apparatus of quantitative determinations. An alternative proposal for the teaching of Natural Sciences, 2nd International Conference, Hands-on Science: Science in a Changing Education, July 13-16 2005, The University of Crete.

[13] Robot means any (mechanical) device capable of performing (pre-programmed) physical tasks (e.g. moving, controlling other devices, reacting to changes in their environment, etc.) and may be considered as the evolution of automata. Robots may be controlled by a human (for example the different kind of probes used in the exploration of earth or space and in surgery) or be controlled by appropriately programmed computers separate from (or being part of) the robot construction. Although the popular notion of robots relates to *humanoids* (former term used *androids*), robots may have any form appropriate for the task they were constructed for. The word *robot* (originating from *robotovat* meaning to work, to serve) appeared for the first time in the play RUR (Rossum's Universal Robots) by the Czech Karel Čapek in 1920 to describe humanlike creatures obeying a master. They are now very popular in (science) fiction.

[14] Dimitriou A., Chatzikraniotis E., "the educational robotics as a tool of skill development for problem solving: Practice with LEGODACTA environment" (in Greek), 2nd Conference for teachers on "Development of Information technologies and Communication in education practice", Syros, May 2003

[15] The LOGO programming language and environments are associated with

constructivist educational philosophy and are designed to support constructive learning (http://el.media.mit.edu/logo-foundation/index.html).

[16] Seymour Papert, MIT Professor Emeritus, is a mathematician and one of the early pioneers of Artificial Intelligence. Born and educated in South Africa, where he participated actively in the anti-apartheid movement, Papert pursued mathematical research at Cambridge University. He worked with Jean Piaget at the University of Geneva from 1958-1963. Papert is the inventor of the Logo Computer Language, the first and most important effort to give children control over new technology. He is the author of Mindstorms: Children, Computers and Powerful Ideas (1980) after which the LEGO ™ Mindstorms (to which Papert is on the advisory board) were labelled (see http://www.papert.org/, http://papert.www.media.mit.edu/people/papert/, http://www.connectedfamily.com/main.html).

[17] http:/www.lego.com/education

[18] Tsovolas S., Komis V., "Teaching basic programming concepts in optical programming ROBOLAB environment" (in Greek), 3rd Conference: Teaching Informatics, University of Peloponnese, Corinth -Greece, October 2005

[19] The goal of constructionism is "giving children good things to do so that they can learn by doing much better than they could before (Papert, S. (1980). Mindstorms: Children, Computers, and Powerful Ideas. NY, New York: Basic Books.)." Is a natural extension of constructivism and emphasizes the hands-on aspect. Papert discovers ways in which technology enables children to actively use knowledge they have acquired.

[20] Costa M., Fernandes J.F., "Growing up with robots", Hsci2004 – CoLoS. Summer School, Ljubljana, Julie 2004.

[21] See also the relevant activities in the Hands on Science network at http://www.hsci.info/.