Paper presented at the 9th International Conference on Hands on Science – Hsci2012, 17-21 October 2012, Antalya, Turkey, http://www.hsci2012.org/.

Teaching Educational Robotics for Schools: some retrospective comments

Simos Anagnostakis and P. G. Michaelides
Department for Primary Teachers Education, The University of Crete, GR-74100 Rethymno-Crete, Greece
sanagn@edc.uoc.gr michail@edc.uoc.gr

Abstract. *The welfare of modern 'knowledge based societies' depends largely on an effective education, especially in the areas of Science and Technology. The Laboratory of Educational Robotics has been proposed as a teaching environment promoting effective education. We have, for a number of years, delivered courses on Educational Robotics to various classes including in-service and pre-service school teachers and students in primary and secondary schools. Main results, related to formal aspects of the teaching such as the objectives, the selection of the syllabus, the students' achievements and the course evaluation, the feasibility of educational robotics as a school subject etc have already been published. In this work we present non-structured observations related to other aspects, e.g.: a/technical, such as the differentiation between computer programming and programming for robots where real time situations and response to events must be resolved, b/aspects related to informal training, such as the behaviour of trainees, either school students or in-/pre- service teachers, the feasibility of educational robotics as a teaching environment, etc..*

Keywords. Educational Robotics, Teaching, Teachers Education.

1. Introduction

The welfare of modern 'knowledge based societies' depends largely on an effective education, especially in the areas of Science and Technology. The 'Laboratory of Educational Robotics' has been proposed as a teaching environment promoting effective education. We have, for a number of years, delivered courses on Educational Robotics to various classes including in-service and pre-service school teachers and students in primary and secondary schools. The main objectives of this course include:

a. understanding the basic concepts of robots,
b. familiarization with the programming of robots,
c. apprehension of the possibilities and limitations of robots,
d. use of educational robotics as a teaching environment in a similar way to the LOGO© teaching environment to which, educational robotics is an evolution.
e. development of problem solving skills,
f. development of self learning skills.

The last objective is essential because developments in this area are very rapid and the teachers (in- and pre- service) should be able to retain any relevant competence they have acquired. To meet this objective, we used a teaching approach evolving from problem based learning to project based learning while inquiry based learning techniques are used [1] especially to 'debug' (correct) or improve the robot programming.

Into the syllabus the following are included:

g. familiarization with the materials used (Lego© Mindstorms©). After presenting the basics of the construction and of the robot programming, students are encouraged to experiment making simple constructions and programs. They are asked to foresee the effect of their programming, test its correctness and try to plan an error correction strategy.
h. simple robot construction under guidance. Students are asked to construct simple robot artefacts, program them to perform tasks with increasing complexity. In every step they are asked to rethink shortcuts in their programming with advances to more complex programming tools.
i. either: a/design and construct a robot on their own to participate in a robot contest or b/design and realize a teaching in schools.
j. design and, if feasible, implement, part of a smart house or another complex (e.g. a production line, a service queue …). This is given as a drill of self-learning activities.

In all steps, students are encouraged to seek and use knowledge relevant to the task from other subjects, especially Science and Mathematics.

Main results, related to formal aspects of the teaching such as the objectives, the selection of the syllabus, the students' achievements and the evaluation of the course, the feasibility of educational robotics as a school subject etc have already been published elsewhere [2], [3], [4] and [5], while, aspects related to the development of self learning skills (course objective f above) are presented in [6].

In this work we present in **2. About the course** some details on the course while in **3. Commentary** we present non-structured observations related to:

k. technical, e.g. the differentiation between computer programming and programming for robots where real time situations and response to events must be resolved,

l. aspects related to informal training, such as the behaviour of trainees, either school students or in- and pre- service teachers, the feasibility of educational robotics as a teaching environment,

m. other aspects.

2. About the course

Administration. The course is included as an optional choice in the area of Informatics in Education of the Department for Primary Education of The University of Crete. Graduates of this Department are qualified to be appointed as teachers in primary schools. The course is taught every or every other semester to students on the 5th or greater semester. Most of these students have already completed their basic courses in Science and in Methodology of Teaching. Their majority are computer literate. In the announcement of the course there is no formal prerequisite of previous attainments or of specific previous knowledge.

Materials used. The equipment used was the LEGO© Mindstorms© because their purchase was easier (http://mindstorms.lego.com/). It has the added advantage that its parts are familiar to most (almost all) of the students. The programming was made on PCs with Windows© or Macs with OSX© using the Robolab© Software supplied by LEGO©, an icon based programming language.

Teaching. The course was delivered in intervals of three teaching hours per week for at least 13 weeks. Students however were free to use the laboratory for more hours, if they wanted to prepare for their assigned tasks or for further study. Students work in groups of two, three or 4 (only exceptionally when many students enrol to the seminar. During the first 3 weeks, students are introduced to concepts related to robots and robot programming (indicating also applications using robots). They also use the equipment to become familiar with the parts, the sensors, the robot unit, the programming language …. During the next 4 weeks students are assigned tasks of constructing specific robots performing relatively simple tasks, the objective being to become familiar with the peculiarities of robot programming, i.e. response in real time specific events. They should also start planning their strategy for their choice to teach in school or to participate in the contest (see i above) a task which has to be completed within the next three weeks together with their study on the concepts of smart home or other applications (see j above) which have to be presented and discussed during the next two weeks. The last week is devoted to retrospection and assessment. In all stages students are asked to optimize, at least once, their completed tasks. A logbook is required to be kept from the students in which, after every 3 hour session they have to fill in retrospectively their work and other comments (e.g. cooperation in the group, problems …).

Differentiations. Within the above organizational frame, differing arrangements are made in order to observe specific aspects such as the effect of detailed instruction, the effectiveness of different teaching approaches, the influence of previous knowledge of students in programming or in technology, etc.

Remarks. The arrangements described in administration ensure best similarity to the in-service school teachers. Mentor type [7] teaching was implemented by the authors of this work (in some cases external observers were also used to check on the observations). This course, adapted as intensive training seminar, is also taught to in-service teachers in Greece and to school teachers from Europe (as a Comenius seminar). Specific parts of it have also been adapted and taught to school children and to school teachers as awareness courses on educational robotics. In all teachings an assessment was included. The assessment of the course was based on teachers observations (including the students' achievements in final examinations), on anonymous Questionnaires from the students, and on teachers – students discussions during and at the end of the course.

3. Commentary

From the assessments following every teaching of the course, the achievements of students from the different classes which are related to cognition and knowledge are similar. In all classes students performed well, succeeding with high marks and with zero drop-out [8]. There was no difference between boys and girls apart from a slight, not statistically significant, tendency for girls to complete their tasks sooner. Although all students agree that it is a very demanding course they also report a very positive opinion for the course adding that they will take a similar course and that they will recommend this course to other students. We interpret this as an indication of active involvements of the students to the learning process. Students at all levels i.e. school students, university students (pre-service teachers), and educators (in- service teachers) seem to respond successfully, although no previous technical or programming skills were required from them.

Learning to use effectively educational robotics the following specific points are noted:

- The computer programming background of students from school is within the frame of 'linear programming' while programming of robots is based on responses to events, such as sensor readings, time period elapsed, etc. It seems that students have difficulties to apprehend the difference especially the students with sound background in computer programming from school. Best way we have found is to assign them a related specific task and provide to students with mentor type guidance to help them complete the task.
- Similar remedies should be used to apprehend the time scale between the processor clock and human behaviour. For example, assigning the task *wait to hear a sound then start the motors and wait to hear a 2nd sound then stop the motors* students usually program the robot as *wait for sound sensor to be above (a high value e.g. 60)→start motors→ wait for sound sensor to be above (a high value e.g. 60)→stop motors* and then are surprised that the artefact robot does not behave as expected and conclude that their program does not run properly although we assure them that their program completed successfully. The clue is to analyse what *2nd sound* means (i.e. *sound level from first sound should drop to very low level and then check for the second sound*) they realize that the time the robot processor takes to execute the commands is within the time duration of the first sound which is misinterpreted also as *2nd sound*.
- Comparison of differences and similarities between the commands *wait for an event* and *loop until an event takes place* is learned effectively by trying to complete tasks specific to these differences and similarities. This seems to be essential to programming for more complex events for example checking more than one sensors, conditions, or situations. These are tasks which promote logic skills and also creative thinking and, possibly, lateral thinking.
- Many students use the arrangement to be in the laboratory outside teaching hours, some to cover up falling behind schedule but most to extend their study on the subject.
- All students report that the will remember always the project, competition or teaching to schools, assigned to them (see point i above). Also they will remember the cooperation and their efforts to complete tasks assigned.

A significant part of some of the objectives, for example d, e and f, is pursued by informal learning through discussions in the groups. We believe that this approach has longer lasting effects as it develops attitudes which may be used by the students in their professional career compensating the lack of learning by society interaction (in a Vygotski context) and the insufficient or expensive formal training available. We have studied this aspect (see details in [4] and [5]) by concurrent comparative teaching in two similar classes. In class A the assignment of tasks took place very early (e.g. from the stage to open the box and start working) and with minimum guidance while in class B there was close guidance at the first stages of familiarization and basic techniques to use the robotic materials. Main conclusions are summarized below:

- In class A students were able to construct and operate simple robots earlier than students in group B. However, in the end there was no difference to the marks achieved between the two classes.
- Students in class A seem to have a better understanding of the subject (they complete there complex projects earlier and with a wider variety of strategies) and report more positive opinions about the different aspects of the course.
- All students note that the challenges to complete themselves the tasks boost up their

self esteem and they liked it with those in class A being more enthusiastic.

- In all the groups there was satisfactory cooperation of different kinds. However, there was a tendency in groups of class A to function on a peer scheme without strictly prescribed roles while in groups from class B the tendency was to function in a role playing scheme (i.e. facilitator, constructor, programmer …).
- Cooperation and completion of the tasks assigned was more efficient when the members of the group adopted as their own the objectives of the task. This led us to negotiate with the groups which specific task between equivalent ones to be assigned letting the group to choose.
- About half of the students in both groups report as the most negative aspect of the course the 'bureaucracy' to fill in the logbook of their activities during the course – this is, however an essential constituent of the teaching approach adopted.

All students report the course as very demanding, however they embark of their own on other non required relevant tasks, for example translate the English manuals into Greek, organizing related events (festivities) ….

The majority of the students report that they consider themselves able to teach a similar subject in school or to use educational robotics in their teaching justifying their opinion on the teaching approach they were exposed to and which they are going to use. It is notable that almost all of the negative responses 'put the blame for their negative responses' to the lack of materials in schools and to the 'rigidity' of the school curriculum, namely is to causes unrelated to their competences.

From the observations of the teachings that our students effected in schools, we note:

- Students' teaching approach was within the frame they were themselves exposed as described earlier although, due to time restrictions, they not always allowed enough time for pupils' deliberation.
- They were very inventive to cover the robot programming task. Instead of using the computer immediately, they produced cards with the commands and asked pupils to arrange them the way they think it will work, study it and comment on the sequence constructed and, afterwards, implementing and actually testing it. This proved a very time and concept effective tool.
- With one exception, to comment later, in all teachings:
  - Pupils show a vivid continuous interest (for 2 or 3 hours!) and they are asking to repeat it at a more advanced level.
  - Although groups were formed, pupils were transferring themselves between the robot sets assuming every time different roles, forming thus continuously changing groups. When succeeding in a task they were going to demonstrate their achievement to their fellows in other groups.
  - Pupils were assuming any role (facilitator, constructor, programmer…) interchangeably when moving between groups.
  - Pupils revealed real creativity to suggest robot applications and modes of implementation.
  - Pupils acquired essential concepts of robots, of their functioning and of indicative applications as was found from the assessments following the teaching interventions.
- In one school there was an imbalance between construction of the robot artifacts and the programming towards which pupils focused their interest. It was found that pupils there were mostly immigrants from former East European countries who had not experience with Lego© type toys, they were, however, exposed to computer and other electronic devices and were interested in the nice Mac Book© type computers used.
- In a test case, teaching was effected by our students within the frame of their degree dissertation to pupils of a problematic school in an isolated mountainous area [9], [10] and [11]. In this school pupils had lost their interest in school from which they did not expect anything useful to their lives, had developed offending tactics and a large percentage was classified as having learning difficulties and attention problems. These pupils, after a short first stage of indifference and suspicion, realized that the concepts involved could be useful to their intended occupation (mostly sheep farmers), showed an increasing interest and get actively involved for the whole teaching (3 interventions, 3 to 4 hours each). Moreover they showed real ingenuity in constructing the robot artefacts. Their interest to school was revived and they started visiting the University to learn more on the various options. Most of these pupils (grown up adults now) keep a contact with the

authors of this work. Similar observations were made in another similar school with a one time intervention.

- A number of our students participate voluntarily to the Pan-Hellenic Educational Robotics Competition (WROHellas) an indication of their interest while some of them have won prizes, an indication of an effective learning, at least at the knowledge level.

5. Summary

Educational Robotics, an evolution of the LOGO© environment is imperative to include in school activities, especially in compulsory education, either as a teaching environment or as a subject aiming to Science and Technology literacy [12]. Our studies on different parameters towards this introduction have shown that this is feasible and, using the teaching approach we have described, it is also compatible with the general objectives of a humanistic education [13].

5. Acknowledgements

This work in its current form has been partially financed by the European Commission (project "Pri-Sci-Net" Grant agreement no. 266647). The views expressed represent the author. Neither the European Commission nor the authors may be held responsible for any use of the information provided here.

Informal discussions during teaching in The University of Crete with A. Margetousaki for her overall help and observations are acknowledged.

6. References

[1]Problem based learning, Inquiry based learning and Project based learning are teaching approaches within the broader scope of constructivism. For the purposes of this paper, we use the following simplified working definitions: In problem based learning students are guided to obtain knowledge through their attempts to solve the problems or answer the (open type) questions posed by the instructor. In inquiry type learning students face also the requirement to think up and apply appropriate techniques to discriminate between different possible alternatives to their solutions or answers. In project based learning, the problems and the questions students are faced are connected towards the making of a project (a construction, an essay, a study …). See more in relevant literature.

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

[3]Simos Anagnostakis, P. G. Michaelides, 'Results from an undergraduate test teaching course on Robotics to Primary Education Teacher – Students' 4th International Conference on Hands-on Science, 23 – 27 July 2007, Universidade dos Açores, Ponta Delgada, Portugal, Proceedings pp. 3-9 http://www.hsci.info/hsci2007.html,.

[4]Anagnostakis S., Margetousaki A., Michaelides P. G., 'The Feasibility of a Laboratory of Educational Robotics in Schools (in Greek)', 4th PanHellenic Conference on the Didactics of Informatics, University of Patras, Patra, 28 – 30 March 2008 (http://www.ecedu.upatras.gr/didinfo/).

[5]Margetousaki A., Anagnostakis S., Michaelides P. G., 'Informal Learning in the context of Educational Robotics (in Greek)', 4th PanHellenic Conference on the Didactics of Informatics, University of Patras, (http://www.ecedu.upatras.gr/didinfo/) Patra, 28 – 30 March 2008.

[6]P. G. Michaelides, Problem Based Learning in Science and Technology teaching in the Department of Primary Teachers Education of the University of Crete, presented at the 9th International Conference on Hands on Science – Hsci2012, 17-21 October 2012, Antalya, Turkey

[7]Traditional tutoring aims to the objectives of the teaching referring to cognition while mentor type teaching, without neglecting these objectives, puts priority on guiding the student to feel confident and become able to solve his/her problems in general – see more in M. Anne Powell, M.S.W., Academic Tutoring and Mentoring: A Literature Review, California Research Bureau, California State Library, 1997 available at http://www.library.ca.gov/crb/97/11/97011.pdf (visited Aug. 22, 2012).

[8]High drop out rates are observed in other courses. In the area of Science, Mathematics and Technology drop out rates may raise to 50% especially if the course includes activities such as a construction, Science measurements, conducting experiments, etc. However, students completing these courses usually achieve high marks. Similar high marks are observed also to students completing this course although drop out rate is zero.

[9]Kalamara Thomais, Educational Robotics in school. A case study in Middle school of Krana', degree dissertation in the Department for Primary Teachers' Education of The University of Crete, Rethymno, 2009 (in Greek).

[10]Staikou Constantina, 'Educational Robotics in school. The prospect of teacher's self training', degree dissertation in the Department for Primary Teachers' Education of The University of Crete, Rethymno, 2009 (in Greek).

[11]Stoumpou Christina, 'Educational Robotics in school. The feasibility of teaching in middle school', degree dissertation in the Department for Primary Teachers' Education of The University of Crete, Rethymno, 2009 (in Greek).

[12] As contemporary Societies are based on Science and Technology (S&T) developments, Science and Technology Literacy (STL) are essential for the welfare of these societies. As more and more regulations (laws, decrees …) are dependent on S&T developments, STL literacy is also crucial for Democracy as a system where citizens participate to the discussions and influence the decisions on their own capacity and not as followers of a politician or Faithfull to a dogma. As developments in S&T are very rapid, STL cannot be acquired (in a Vygotski or Bakhtin framework) through the interaction with the society (there is no related experience in the society) leaving as the only alternative the formal education and training, especially the compulsory education which is addressed to all citizens.

[13] *To come to a more fundamental cleavage; there can be no agreement between those who regard education as a means of instilling certain definite beliefs, and those who think that it should produce the power of independent judgement. Where such issues are relevant, it would be idle to shirk them……..* passage from the book 'On Education, Especially in Early Childhood, 1926) 'by Bertrand Russell (1872-1980), the third Earl Russell, Mathematician (Logic-see Russell's paradox), one of the greatest philosophers who wrote many of his works in jail where he was imprisoned because of his political activity (peace movements during the era of post WWII cold war).