Robotics at primary and secondary education levels: technology, methodology, curriculum and science

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Abstract. This paper presents the authors'experience in using robotics at different education levels. They have been involved for more than one year in an on-going project (TERECoP) which deals with the use of Robotics in Education. This has permitted to the authors to investigate different issues of practiacl educational robotics, e.g. like methodology approaches and technological issues, but also to address more fundamental questions like: "What is robotics at school?" or "How we can design good robotics learning experiences?". Within this context, the authors present in this paper some methodological considerations first, and then describe a pilot course of the use of robotics for teacher's sciences. Afterwards they discuss on several issues in the use of robotics in education, like curriculum or science and technology dissemination.

1 Introduction

Since December 2006 the authors have started to work with five other partners - Aspete (Greece), IUFM (France), UP-RO (Rumania), CUNI (Chequia), and IT+Robotics (Italy)- in the TERECOP project (Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods, http://www.terecop.eu/).

The overall aim of the project is to develop a framework for teacher education courses in order to enable teachers to implement the robotics-enhanced constructivist learning in school classrooms, and report experiences from the implementation of this framework.

Several initiatives have been carried out in different countries with the goal of fostering the interest of children in science and technology using robotics. Some global initiatives, such as FIRST (For Inspiration and Recognition of Science and Technology, http://www.usfirst.org) look for sponsors of local, regional, and international robotics events (http://www.firstlegoleague.org/). In our countries several educational robotics experiences are carrying out like http://www.scuoladirobotica.it/ (in Italy) or http://www.descubrelarobotica.es (in Spain).

Programmable robotic construction kits are powerful tools to enhance students' learning in science and technology. Several curricula exploit their usage in different education levels. It has been proved that this kind of activity promotes the creative attitudes of the students and their communication and cooperation abilities. Moreover, studying and applying robotics lead students to manifest interest also towards scientific/technological subjects (e.g. mathematics, physics, etc.).

Within this context, the authors of this paper are investigating several related aspects.Sometimes new robotics curricula just introduce robots by them-selves , so the first question is:

- Are the educational robotics courses using adequate methodological approaches?

We see that the current curricula do not include this kind of robotics activities, so the second question is:

- How to integrate such activities in the curricula?

A big effort is being made in using robotics for science & technology dissemination, and it seems that it is working, so we are asking the third question is:

- Could we design interdisciplinary activities based on robotics, able to be integrated in a scholar curricula?

In this paper we want to focus on these three aspects, at the same time we are relating the history of how we prepared, carried out and evaluated (work on progress) a teaching training course in the use of Robotics & Education at Rovereto, Trento, Italy during November and December 2007, within the scope of the TERECOP project.
This paper is organized as follows. Section 2 outlines the main objectives of the TERECOP project. Section 3 discusses on different aspects related with our methodological approach. Section 4 describes the pilot teacher's training course carried out in November-December 2007. Section 5 presents some concluding reflections that could give new ideas for the next training courses.

2 The TERECOP project

We outline on this sections the main objectives of this project. For more information you can refer to the web site (http://www.terecop.eu/) or to (Alimisis et al 2007). A first premise of this project concerns the implementation of constructivist-constructionist methods not only in classroom, but in teacher education as well. A second premise is referred to the technology-enhanced learning as occurred in the implementation of different kinds of curriculum innovation in the classrooms. A third one is related with the emerging need for teaching as a research-based profession and for the creation of a culture in which researchers and teachers can create a shared body of knowledge. The TERECoP project's aim and ambition is to contribute to fill in this gap suggesting a constructivist model of teacher training in these new technologies As one of the main purposes of the project is to design, implement and validate a robotics based teacher's training curriculum, we collaborated in the course design and realized six different implementations, one for each partner-country. Each partner is free to choose the profile and education teaching level of the "trainees". This is a premise to have diverse groups with different professional position (in service or not), with different background and experience, with different teaching subjects, possibly with different motivations, etc… During the second year of the project pilot courses are carried out, with an evaluation phase giving important feedback data that should be worked on by the researchers team during the third and last year.

So, TERECoP project would like to be a beneficial one for teachers both at national and European level enabling them to introduce robotics in their classrooms in a constructivist framework. We also hope that its outcomes will constitute a significant educational advantage for students (end–users), for teachers and for the science and technology education in general.

3 Methodological approach

Our methodological approach tries to take into account the different aspects involved in a constructivist teaching-learning process, within a concrete scholastic context. To be clearer we have structured this section in four subsections, each addressing a specific subproblem: the learning processes, the learning outcomes, the learning strategies and the learning tools.

3.1 Learning process

The constructivist theories of Jean Piaget argue that human learning is no the result of a transmission of knowledge, but an active process of knowledge construction based on experiences gained from the real world and linked to personal, unique pre-knowledge (Piaget 1972). On top of this, the constructionist educational philosophy of S. Papert added that the construction of new knowledge is more effective when the learners are engaged in constructing products that are personally meaningful to them. Constructionism (Papert 1992, Papert 1980), is a natural extension of constructivism and emphasizes the hands-on aspect. Vygotsky's (1962) theoretical framework stands that social interaction plays a fundamental role in the development of cognition. Another aspect is the idea that the potential for cognitive development depends upon the "zone of proximal development" (ZPD): a level of development attained when children engage in social behavior. Full development of the ZPD depends again upon full social interaction (teacher guidance or pupil collaboration). The expertise (to attain competent skills) in "commanding tasks to robots so that they have certain behaviours (with a goal in mind)" can be the object of constructivist education (on the teacher's side) and constructivist learning (on the student's side). For this we have to select and adapt to our objective the most pertinent characteristics of the theories of Piaget and Vygotsky, known as cognitive reconstruction theories assuming a constructivist education-learning. The design of good education-learning experiences (constructivist ones) with robots has to be done taking into account the following points:

- Proposing to the pupils different "classes" of problems to solve (tasks of a same class); the itinerary to follow has to produce a meaningful learning and needs to have an adequate sequence of learning problems according to the pupil's knowledge and profile.
- Cooperating, teachers and pupils, for the resolution of the class of problems in the "zone of proximal development" (Vygotsky)
- Integrating finally every class of solved tasks in technical or technological procedures more general and abstract.

3.2 Learning outcomes

The fundamental differences between "meaningful learning" and "memoristic learning" are given in (Novak and Gowin, 1989) and in our case we are looking clearly to make a significant effort in order to make the pupils to acquire meaningful learning.

In fact the learning outcomes come from the combination of the learning process, and the learning strategies, and as it is said in (Ausubel, 1968) it is important to understand that the learning process and the learning strategies are independent, even they are interacting.

So it is necessary to "tune" adequately the learning strategy and the learning tools in order to create the correct learning situation to the pupil profile. In our case we have chosen a PBL strategy to create a didactical situation based on exploration and enquiry learning, producing the adequate learning tools.

3.3 Learning strategy

The problem-based learning (PBL) is a method that challenges students to "learn to learn"; student groups are seeking solutions to real world problems, which are based on a technology-based framework used to engage students' curiosity and initiate motivation, leading so to critical and analytical thinking (Boud and Feletti 1997) (Savin-Baden 2000).
The main interest of PBL in our approach is that it allows us a different approach to curriculum and course design, crossing disciplinary boundaries, and tolerating a degree of uncertainty about outcomes. This can be an interesting way for us to deal with

different education levels (for the moment primary and secondary) and to work on a curricula where robotics can be used both with scientific disciplines (Maths, Physics, Computing, etc..) and with others related with social sciences, linguistics, etc…

During the PBL learning process and within TERECoP several stages have been identified: engagement stage, exploration stage, investigation stage, production /creation stage and evaluation stage.

3.4 Learning tools

To finish the methodological observations we should add that the learning tools to create the learning situations within our context of using robotics in education has been influenced by the theory of Chevallard (for the teaching practice) and by the theory of Douady (for the tool-objects didactics).

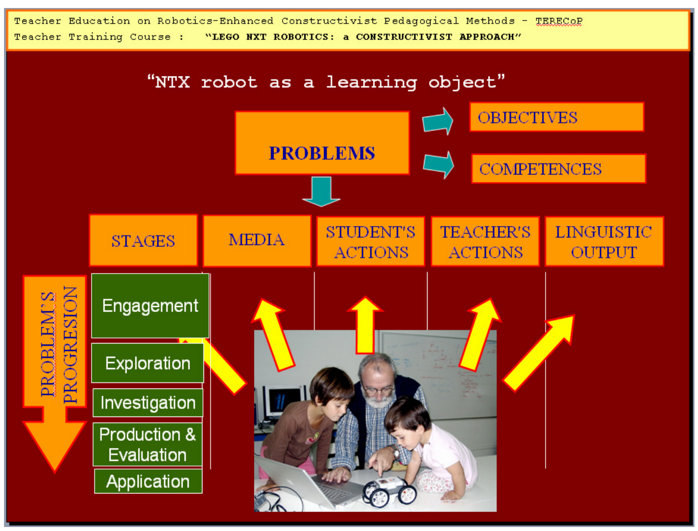


Fig. 1. Slide extracted from the material of the course

The anthropological approach of Chevallard is a theoretical framework for research in the didactics of mathematics, where he introduces the "*praxeology*", a word that combines both praxis and knowledge (~logos), and means that a mathematical activity is a mixture of practice and knowledge. The main goal for a mathematics student is to acquire and learn the knowledge (decided by the mathematics society) and the means to do it is to practice mathematics. These two concepts are precisely the main concepts in the Anthropological Theory of Didactics developed by Yves Chevallard (Chevallard, 1999)

For Douady (Douady, 1986), a problem, considered as a source of learning and of creation of new knowledge, must lead students to a reflection, to a research aiming at the full and correct solution of the problem. And in this process he recognizes several stages (Maranhão, 2006): old phase, research phase, explanation, new implicit, validation. In some of them the teacher needs to propose new problems which use their previous knowledge, and which should help students to work out the problems partially, but not completely.

4 Pilot training course

The methodological approach described in Section 3 has been "embodied" in the first pilot course of TERECoP. The different learning materials, learing situations (i.e., the didactical experiences and the practical activities) have been designed following the theoretical/philosophical guidelines described in the previous section. The first pilot course has been organized in the Town Museum of Rovereto (Trento), one of the Italian partners of TERECoP project. The Town Museum of Rovereto is one of the most lively and sound divulgation-center in Rovereto. The "trainers" were the partners of DEI (Univ. of Padova, Italy), UPNA (Public univ. of Navarra, Spain) and Rovereto Museum (Italy).

4.1 Preparation

The 15 teachers to be taught, from now on "trainees", came from schools in Trentino and Veneto (two northern regions in Italy). They were all science teachers in service, in some cases with considerable experience. We can recognize two categories:

- teachers who had already used robotics in their teaching laboratories;
- teachers who are used with lab teaching, but had no previous experience with robotics.

The first group was identified within the collaborators of the Museum, particularly among members of the already constituted group "Scienzeonline": these were the first to join and then have involved their colleagues in the second group.
In fact, during the course we divided the trainees in heterogeneous groups especially in terms of skills in using robots in order to create profitable partnerships and synergies within the individual teams.
The course was divided into four initial work-days (in 2 weeks), with a subsequent experimentation by the trainees of the acquired methods and competences in their schools and with their pupils.

Two recalls are planned (in November and in December), in order to allow the trainees to interact with the Project Terecop trainers during the experimental steps, whereas the Discovery Film Festival, with its usual section dedicated to educational robotics, can host demonstrations and results of the project-based school activities that will follow the training phase.

W1	W1	W2	W3	W3	W4	W5	W6	W7	W8	W9
d1	d2		d1	d2			d1			d1
3h	*7h*	*e-w*	*6h*	*8h*	*e-w*	*e-w*	*3h*	*e-w*	*e-w*	*3h*
9 weeks (6 face-to-face, Nov.-Dec. 2007)										
4 periods of teaching (2-2-1-1 days)										
3 periods of personnal e-work (e-w) with e-class (1-2-2 weeks)										
30h in the face-to-face sessions (3-7-6-8-3-3 hours)										

Fig. 2. The planning of the course

4.2 Carrying out

The course aims to reach two main objectives for the scientific education:

- to assure scientific competences necessary to face the nowadays world challenges;
- to design activities and curricula able to adapt disciplinary structures to the learning dynamics

Activities (over a total of 30h)	hours
Introduction	1
Theoretical background	0,5
Self-presentations	0,5
Didactic contract	1
Setting groups	0,25
Robotics in Education	0,25
Workshop I	6
Discussion and conclusions	1
Brainstorming	1
Talk on Robotics (VC)	1
Workshop III	3
Discussion and conclusions	1
Workshop III	2
Discussion and conclusions	1
Synthesis on the constructionnist experience	1
Advanced examples on Robotics	1
Workshop IV	2
E-class	1
Plenary group discussion and evaluation	2
Discussion on next activities	1
Discussion on the produced diactical units	2
Final evaluation	1

Fig. 3. Different activities carried out during the course

The trainees have been guided in building ‘intelligent’ machines, following all the steps of the construction, from the design to the realization, passing through errors and frustrations, but with clear objectives; moreover educational paths will be designed to introduce robots in the teaching of scientific subjects, making the trainees confident with the constructivist education following the aims of the TERECoP project.

The objectives of the course are:

- to build competences for designing educational laboratory project-based activities;
- to learn to use innovative didactic methodologies and technologies that the course propose;
- to consolidate the ability of working in groups, also through the use of ICT tools.;

working on

- realization of the proposed activities, with communication and guided group-based work
- pedagogical and methodological reasoning on the educative management of the activity.
- to consolidate the ability of working in groups, also through the use of ICT tools.;

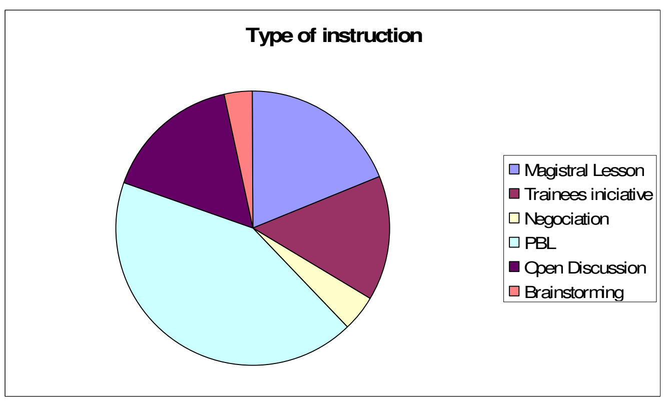


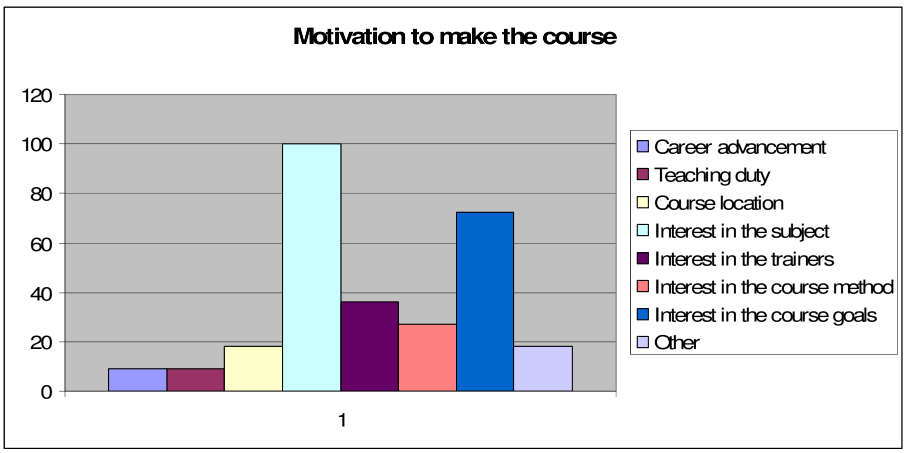
Fig. 4. Different types of instruction used for the course.

Figures 3 and 4 show respectively the kind of activities that have been carried out by the trainees, and the type of instruction used by the trainers to promote these activities and has been computed using the number of hours of every activity 8figure 4) and also the description of the agenda, which records what activities and for how much time have been finally carried out during the course.

4.3 Evaluation

We have provided to the trainees a virtual support for the course both for practical teaching purposes (a repository for the materials and means for communicating) and for evaluation purposes, as it allows the trainers to follow and tutor the trainees .
As the course is not yet finished, the evaluation is on-progress. The main idea is to analyse:

- The video-recordings of most of the sessions (to observe the didactical situations)
- The individual written questionnaire the trainees have to fill
- The group interview they will have during the last meeting
- The didactical units produced by trainees following the course methodology.



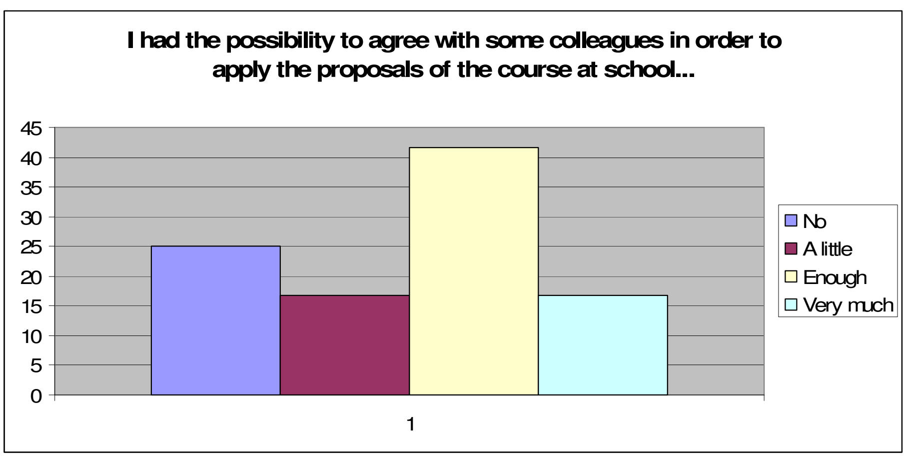


Fig. 5. Examples of answer to the individual questionnaire

1.	**About the Constructivist/constructionist methodological approach**	
	a.	Interesting practical approach
	b.	Interesting related theoretical foundations
	c.	Appropriate to motivate intellectually the students
	d.	Every student needs to walk on his own path (no honest possible shortcuts) dedicating not easily predictable amount of time
	e.	Often the usual activity in a lab follows constructivist ideas even though the teacher is not aware of this
	f.	In traditional classrooms the management of brainstorming, cooperating workgroups, etc. is quite difficult
2.	**About the HW/SW**	
	a.	An initial learning is needed to able to work with: need of training both for trainers and students
	b.	NXT can be a valid tool: motivating, versatile (even a high cost)
	c.	The use of a large variety of programming environment and sensors is interesting
3.	**About the difficulty to prepare an effective didactic unit**	
	a.	Good motivation for scientific topics (for instance: programming and computer science, biology, physics, mathematics, earth sciences)
	b.	It must be built considering the type of skill/competency you want to work with/acquire
4.	**About the possibility to apply these ideas to the specific school, to the same type of schools, as an external activity**	
	a.	You need time to successfully apply this teaching/learning technology: the reality of our schools does not leave us so much time at the present
	b.	Common feeling of parents and colleagues about using mini-robotics at school is that students are simply playing and thus the related pedagogical value is not easily appreciated
	c.	Designing interdisciplinary activities is a big challenging issue

Table 1. Principal opinions from the group interviews

5 Some concluding reflections

We have already identified some critical aspects like:

- Organization; a robotics lab is needed and this might seems trivial but it is not always available or easy to realize. A robotics lab means adeguate space for humans and robot to move around and available personal computers and several robot construction kits.
- Groups; we have seen that it is very important to have groups that are able to work in group between the face-to-face sessions.

The evaluation model we are trying to apply must be different to a classical one. In fact the main objective to verify is to see if the trainees are able to construct a robotics based didactic unit, following a constructivist approach.
In the next weeks, we have to finish the evaluation and to see the produced materials. We have to analyse all the recorded material and the evaluation questionnaires sent to the trainees. With all these information we should be able to interpret what happened during the course, and to tune it in order to improve the current format and even the contents.

About the international team (Italian/Spanish) we think it was a very interesting cooperation, both for the trainees (the course became an "international" teacher training course) and for the trainers (we had to deal with an adequate coordination between face-to-face sessions, e-class and international videoconferences; also we have been using three different languages, English, Italian and Spanish and 2 different educational systems). In any case we have seen the importance and the challenge of integrating these differences in order to produce "really effective European" products
Nevertheless, from a European point of view, we think that is an interesting experience and demonstrates a double case of real cooperation, first within the TERECOP project, and then the Italian-Spanish cooperation for this training teachers course.

A first evidence is that we need to have at least two kind of courses. One for in teaching service teachers, with a similar format to the one we did in Rovereto (in about 2 months, with 2 intensive face-to-face sessions). Another one could be scheduled during 6 months, for teacher's students. Anyway in both cases, it seems necessary to provide the trainees with robotics kits and to use some kind of virtual platform to maintain activity between face-to-face sessions.

We have been proposing mostly science & technology subjects to be implemented with the robots (as in this pilot course all the teachers were from these fields). But it seems very interesting to form trainees groups composed of teachers from different subjects, even humanities and arts (possibly from the same institution). In the next course to be carried out in May 2008 we would like to stick on a progressive and constructivist itinerary, to make a clear difference of what it is the robot as the objectof study and what it is the robot as a tool to learn other things, and as a consequence to open this approach to other disciplines not directly related with technology and/or sciences.

This trainee's course is only the tip of the iceberg; the most challenging issue is to manage to have some feedback from some of the trainees when being trainers of their own pupils, in an scholastic context. This should be in the next months one of the issues. Then we may be able to start answering to the questions we had at the beginning, like which activities for which level or how to integrate them within the curricula. But in any case we are sure that with these initiatives we are making are the necessary first steps to try to answer to these questions, and there is no any shortcut.

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