Robotics & Constructivism in Education: the TERECoP project

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Abstract

This paper presents the European project "Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods" (TERECoP). 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 is related with the emerging need for a 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.

Although the role of teacher is crucial for the successful introduction of robotics in classrooms, only few projects have been undertaken to train school teachers in using this, completely new for them, technology. 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. Learning theories, modelling, technology and languages are the main aspects we will have to deal with. The main questions we are currently trying to answer (probably in this order) are: what is "Robotics" at School? Which methodology should we use to apply "Robotics" at school and teacher education? How can we design educational activities (within students' curricula and teacher training courses) once we have answered to the two previous questions?

Our work within the TERECoP project tries to give some answers to these questions. The paper describes the starting point of this project, focusing on the context, on the aims of the project and on the different partners' countries experiences, and outlines the different stages that are going to be developed to implement the project giving a description of every one. Finally some preliminary conclusions are presented.

Keywords

Logo, Lego, Constructivism, Constructionism, Teacher Education, Robotics

Introduction

Research in science and technology education has made possible the development of learning strategies and materials that attempt to meet students' needs and address their learning difficulties, such as computer-based learning environments and microcomputer-based laboratory tools (Niederer, et al., 2003). Nowadays, increasing attention is paid to computer-based robotic activities considered to be a valuable learning tool that contributes to the enhancement of learning and the development of student thinking. Taking into consideration that students have a better understanding when they express themselves through invention and creation (Piaget, 1974), teachers need to provide students with the opportunity to design, build and program their own models. Programming as a general model-building and toolmaking learning environment has been shown to support constructionist learning across the curriculum (Papert, 1992). The LEGO robot, an outgrowth of Papert's LOGO programming language created in the 1960's, partners technology with constructionist ideas.

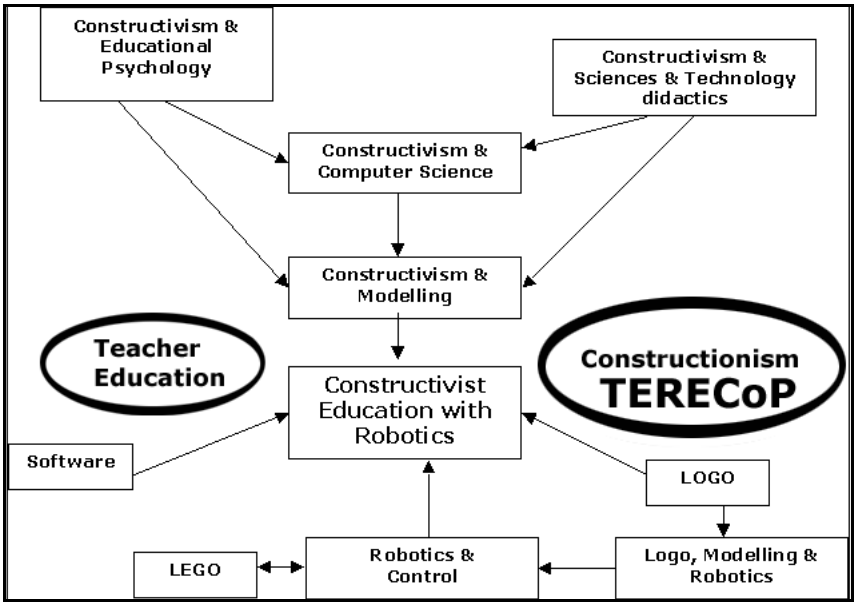

Figure 1 Related fields of constructivist robotics-based education

Logo in its various implementations was for years the main framework where applying the constructionist "way of thinking", and it still remains the natural environment from which to start to develop a constructionist approach of facing new learning challenges. Its turtle-robot works on a virtual environment, where the turtle behaviour is an iconic representation of real behaviours. So, the use of LOGO is well suited to learn by solving environmental problems (e.g. the relation between speed, time and space in a uniform movement), because, in this case, the robot has no side effects in the solving problem process and it behaves as a "virtual perfect robot". But the LOGO environment offers a very poor 'robotic architecture' and some clear limitations, like a 2D scenario, to perform complex tasks (from a classical robotics approach). The introduction of robotic elementary experiences with LOGO is a natural evolution towards a real environment with a real robot where the presence of physical constraints and new input stimuli (real sensors) offers a new learning scenario.

Under this framework, programmable robotic constructions have recently been proposed promising to enhance students' learning science and technology concepts. The LEGO Mindstorms system ([1]) provides a flexible medium for constructionist learning, offering opportunities for design and construction with limited time and small funds. It is comprised of building materials (regular blocks, gears, pulleys and axels) and programming software with an effective graphical interface for developing robotic applications based on LEGO robots.

In the previous versions the available tools were RCX Code and Robolab ([2]), whereas the current NXT version offers a more powerful tool ([3]) based on a customisation of LabVIEW, a well-known controlling and simulation environment developed by National Instruments. All these tools provide draggable icons to represent every programmable robotic element of the kit (motors and sensors) together with simple control structures. Programming a robot results in juxtaposing a sequence of iconised actions, possibly related on events and/or states produced by the applied sensors. The parameterisation of these actions is easily done through the graphical interface. Moreover LEGO NXT offers the opportunity to exploit alternative approaches: its firmware is 'open source', the host-robot communication protocol is well-documented and the descriptions of several different experimentations on controlling/programming the robot are already available. Some of them are based on specific programming languages (e.g. NBC, [4]) whose complexity can be calibrated on the basis of the pupils' level. More recently the Microsoft Robotic Studio initiative ([5]) has produced a first release of the environment which already supports LEGO NXT.

Currently the market offers an increasing variety of robotic proposals that we intend to investigate in the context of our project according to the requirements of different levels of learning and stimulating disciplines. For example you can find already constructed and very simple programmable units, like Bee-Bot ([6]) and the Parallax Scribbler ([7]); kits designed for making artistic creations, like PicoCricket ([8]) which similarly as LEGO Mindstorms comes from the MIT Media Lab researches; much more complex humanoid architectures like Robotis ([9]). More or less all these different options and approaches show that the programmable constructions make possible new types of science experiments, in which children investigate everyday phenomena in their lives both in and out of the classroom (Resnick et al., 1996).

The educational meaning of Robotics in school education, the methodology that should be used to introduce Robotics in school and teacher education and the design of robotics-based educational activities within a teacher training curriculum are among the main problems that the TERECoP project ("Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods") intends to copy with. Figure 1 summarizes the relation between these open problems, constructivism, constructionism, Logo & Lego.

This paper describes our current, and planned for the future, work within the TERECoP project (October 2006-September 2009). The starting point of this project is described in the next sections focusing on the context, on the aims of the project and on the different partners' countries experiences. The different stages that are going to be developed to implement the project are outlined and a short description of every one is given. Finally some preliminary conclusions are presented.

Starting point for TERECoP project

Context of the project

Our project is inspired from

- the constructivist theories of Jean Piaget arguing that human learning is not 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).
- the constructionist educational philosophy of S. Papert adding 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) is a natural extension of constructivism and emphasizes the hands-on aspect. The learners in a constructionist environment build something on their own, preferably a tangible object that they can both touch and find meaningful. 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, 1980).

In this theoretical frame a socio-constructivist view is adopted, where learning is not an individual, but a particularly social and societal activity that means that learning always takes place in a social context. Under such a framework the use of educational technology could contribute to the realisation of

- meaningful learning based on students' own team work with teaching materials;
- authentic learning using learning resources of real-life, occupational situations, or simulations of the every day phenomena;
- social learning: technology supports the process of joint knowledge development; the available e-learning environments can support collaboration between fellow students, who can be at different schools, at home or abroad;
- active-reflective learning: students work on experiments or problem-solving using available resources selectively according to their own interests, search and learning strategies;
- problem-based learning: 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;

So, 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 is related with the emerging need for a 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.

Goals of the project

The implementation of robotics-enhanced constructivist teaching and learning practices in science and technology classes, however, demands that teachers play a new role. This means that opportunities, like exposure to a number of critical examples and experience in designing computer-based robotic activities and integrating them in their classroom practice in constructivist ways, are of great priority. The goal of our project is teachers to be convinced by their own personal experience for the potentiality of robotic technology as a learning tool. Based on this principle, we intend to develop and implement a teacher-training course to support teachers' professional development. Course participants, who will be practicing or in-service teachers, will be provided with opportunities to examine how robotic technologies can be used to promote a constructivist approach to learning under a co-operative and collaborative frame of work.

So 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, and reflect on their experiences from the implementation of this framework. More specifically our objectives are:

- To develop a methodology of innovative collaborative strategies supporting social constructivist teaching and learning, applied both in the teacher courses and in students' teaching and learning.
- To select and organize a repertoire of appropriate robotics-based learning environments that can support robotic activities and produce a set of critical examples for using in a constructivist way with teachers of secondary level in science and technology subjects.
- To test and evaluate the practical implementation of the selected tools both in training courses and in real classrooms situation (by the trainees).
- To create a community of practice between educators and teachers for facilitating and sustaining teachers' professional development in using robotic tools to support their students' learning by active exploration and social construction of new knowledge.

In the pre-mentioned frame of objectives key issues to be addressed during the project are:

- The integration of technological, cognitive, pedagogical, and social aspects in order to design and develop learner-centred technology-enhanced learning environments with an emphasis on technology as a cognitive partner in learning.
- The design of robotics-enhanced activities where learners learn with technology and accomplish cognitive tasks beyond their reach.

In this project we regard that technology alone cannot affect minds. Our curriculum design will follow an innovative constructivist perspective with an emphasis on aligning computer and robotic technology with learning objectives and learners' needs for the purpose of constructing meaning in social learning environments. In such learning environments the focus is not on the individual but on "interactive environments" that include individuals interacting with each other, instructional materials, subject matter, and tools. Computer-based robotics is an innovative technology that can create or support a rich interactive environment encouraging constructivist learning.

The joint cognitive partnership between technology and learners depends on mindful engagement and interaction. Consequently, to engineer a desirable effect with or of a technology requires more than just introducing the technology. Therefore, in this research project we will apply constructivist pedagogy and a learner-centred didactical approach taking into consideration learner's characteristics for an effective technology-enhanced learning design.

Striving for a collaborative learning environment is based on the belief that the inherent dynamics of a necessary mutual process are likely to be more conducive to meaningful transformation, carrying so a sense of greater potential for development. This is highly supported by the development of e-learning communities.

The target groups of the project include

a) student-teachers expected to be educated in a way that robotic technology-based learning will play an important aspect of their future work as teachers or professional educators

b) in-service teachers expected to become aware of the robotic technology-based learning and of different classroom uses and activities for improving their students' learning in science and technology

c) teacher educators expected to be informed for providing similar courses in local level and

d) educational authorities expected to undertake future action on teacher technology-based education and further training

Some elements describing the current situation in some of the partners' countries

Robotics is not included in the official curriculum of **Greek** school education. Some occasional implications are mentioned in literature mainly for research reasons. There have also been a few examples of use of Robotic activities with Lego Mindstorms in private schools as extra curriculum activities (Ekpaidefthiria Douka [10], Phychiko College [11]). Some evening private schools (frontistiria) also use these technologies to teach computer skills to young students (e.g. Interactive Learning [12]).

Nevertheless, educational Robotics seem to be very popular in higher education and especially in Engineering and Computer Science departments, as part of the curriculum or as a subject for extended coursework e.g. at the National Technical University of Athens, National Technical University of Patras, University of Macedonia, University of Crete. Moreover, several research projects in this field have been developed focusing on the use of educational Robotics in primary and secondary education. Frangou and Kynigos (2000) used Lego Robotics with secondary students (13-15 years old) in order to investigate educational aspects of these technologies. They found that through Robotics students can acquire hands on experience on variety of science concepts, develop problem solving skills and progress in constructing physical and computer models. The project "Technical school students design and develop robotic gear-based constructions for the transmission of motion" developed by the School of Pedagogical and Technological Education in Patras investigated how programmable robotic constructions can be effectively used in Technical and Vocational Schools (student age 16-20). In that project students were invited to design, develop and program a robotic construction using the Technological Inventions LEGO Mindstorms Package. The project provided very promising indications that students learn important mathematical and scientific concepts through their own design and programming activities (Alimisis et al., 2005, Karatrantou et al., 2005). Another project that investigated the potential of educational Robotics in teaching programming in secondary education stressed the importance of the interaction between the construction and the algorithm of the software in understanding basic programming structures (Kagkani et al, 2005). Finally, two more research projects focused on primary education. They stressed the cooperative character (Dimitriou & Xatzikraniotis 2003) and the experimental aspect (Karatrantou et al 2006) of robotic activities.

Though Robotics is not officially included in the **Italian** primary and secondary educational system, the interest on educational robotics is rapidly increasing. Apart from the contributions of isolated experiences and advanced laboratories in technical secondary schools and universities, some relevant recent projects, involving both school teachers and experts, are giving impulse to the subject. Among others: Uso didattico della Robotica (educational use of robotics) at IRRE Piemonte ([13]); Costruiamo un Robot (let us build a robot) ([14]); La bottega dei robot (the robot shop), The National Science and Technology Museum of Milan ([15]); Robot@Scuola, a school network involved in educational robotics ([16]); EduRobot, The Institute for Educational Technology of Italian National Research Council ([17]); AmicoRobot, a school network in Milan ([18]). Most of these projects are related to the Lego Mindstorms robotic architecture.

The **Spanish** situation is similar to the previous ones, and the use of robotics in primary and secondary education is very limited and not official at all. In general there are a lot of activities in the field of Robotics in Spain mainly in research or industry ([19]) and there are also a few robot competitions organized ([20]). In some of these competitions the participants are secondary level students. It is also a fact that the different educational institutions (national and regional) are aware of introducing and using computer science & technology at schools ([21] in Catalonia, [22] in Madrid, [23] in Navarra or [24] as the national reference in Educational Computer Science & technology). Nevertheless it is quite difficult to find deep and complete experiences in Robotics & Education. Some of the relevant experiences are the use of LOGO (the approach is similar to ours) at school ([25]), some teachers' initiatives like the project RESS (secondary level experience with LEGO done in 2003: [26]) or personal ones like the web page and materials from the "freelancer" Koldo Olaskoaga ([27]). We found two experiences close to our project; one in Educational Robotics done in Primary school level by Alfredo Rodrigálvarez Rebollo (Director of the public college "San Francisco de Cifuentes", Guadalajara, Spain [28]) with an important effort in integrating these activities within the curricula; the other one carried out by the University of Alicante group called TEDDI, which works (among other research areas) in finding didactic applications of robotics at different levels in school ([29]).

Implementing the project

The project TERECoP started in October 2006 in the frame of the European Programme Socrates/Comenius/Action 2.1 (Training of School Education Staff) and its total duration will be 3 years. 8 institutions from 6 different European countries participate in the project: School of Pedagogical and Technological Education (GR, coordinator), Institut Universitaire de Formation des Maîtres d'Aix-Marseille (FR), Department of Information Engineering – University of Padova (IT), University of Piteşti (RO), IT+Robotics srl (IT), Museo Civico di Rovereto (IT), Charles University Prague, Faculty of Education (CZ), Public University of Navarre (ES). During the 1st year a methodology for designing robotic technology-enhanced constructivist learning will be developed and teacher education courses will be designed. During the 2nd year a pilot and a final teacher education course will be implemented including testing of trainees' teaching activities in school classes. Finally during the 3rd year the evaluation of the courses and the development of dissemination activities will take place.

Expected outputs of the project

An **e-community** will be created to offer for both educators (from the beginning of the project) and teacher-students (during the 2nd and 3rd year) a communication platform including:

- a public space available for all the members of the community (educators and student-teachers) to post their messages and to upload their files;
- a forum to develop discussions on selected topics related to the project subject;
- synchronous and asynchronous communication through bulletin boards, chat and e-mail services.

The e-community intends to support the development of a learning community engaging the teacher–learners in social learning, supporting meaningful conversations among learners and between educators and learners, promoting new perspectives and helping them to construct knowledge in a collaborative way.

A **project web site (**see figure 2, http://www.terecop.eu**)** presents the whole work done in the frame of the project and connects the project with the broad educational community.

Figure 2. The TERECoP Web site

The partners are currently working to develop a **methodology** for designing computer-based robotics-enhanced constructivist learning, applied both in the teacher courses and in students' teaching and learning. The methodology, incorporating results from the relevant research literature (books on subject, educational journals, proceedings of educational conferences, web resources and educational software tools), will outline basic principles, learning objectives and strategies, appropriate technology-based environments and learning activities and some critical examples of robotics-enhanced constructivist learning.

The design of the teacher education courses will be based on the methodology developed in the beginning of the project; this will permit us to design a pilot course curriculum. The design of the course curriculum will include **learning materials** and **evaluation tools**. Emphasis will be placed:

- on the development of innovative collaborative strategies between educators and teachers
- on the selection of expressive or exploratory learning activities that can support social constructivist teaching and learning.
- on the practical use of the selected tools in a real classroom context.

Pilot courses

The pre-mentioned course design will be implemented and evaluated with student-teachers in three different countries by the corresponding partners. From the beginning of the face to face course student–teachers will be invited to participate in an e-community and will have access to e-learning materials. In these courses student-teachers will elaborate on the development of robotics-based constructivist teaching activities and materials for their students. They will be encouraged to create and present joint projects regarding constructivist teaching activities planned to be implemented with school students, and to argue for their choices. The student-teachers will also be encouraged to implement their projects in real school classes, where it is possible, and to evaluate them in cooperation with their tutors. The projects and the evaluation results will be published and discussed in the e-community where educators and teachers will have the opportunity to share and reflect on their experiences.

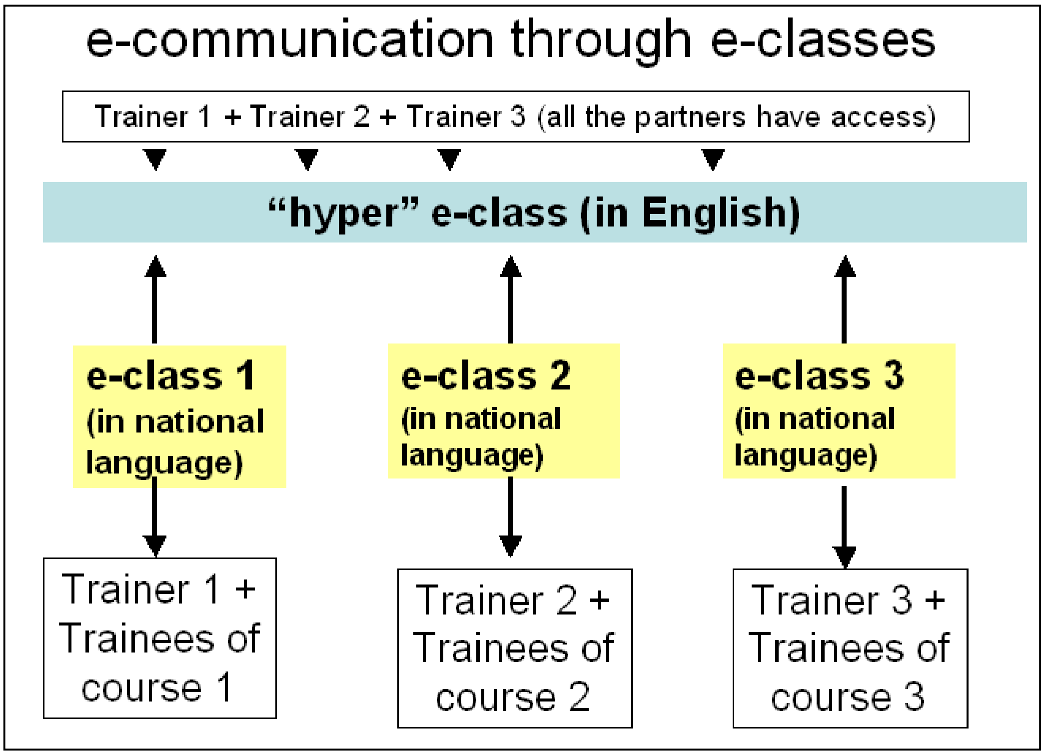

Figure 3. E-classes organization for the pilot courses

Evaluation

An evaluation report on the pilot courses will be presented to all the partners, and using it as a feedback, a revised curriculum of the courses based on the evaluation results will be developed. After that, 3 teacher training final courses will be organized using the revised curriculum and learning materials and combining again the face to face course with an e-class community. The evaluation of the courses will be carried out using the same (revised if necessary) evaluation instruments developed for the needs of this project based on data collected in the courses and on data collected from the implementation of students' projects in a real school class. In the end of this process a final revised curriculum based on the results and findings coming from the evaluation process are expected to be obtained.

Courses in the future through the Comenius Catalogue

The final course, as it will have been refined in the end of the project, will be offered for in-service training of secondary science and technology teachers from the whole European educational community through the Comenius Catalogue following the same constructivist pedagogy and applying the learner-centred approach developed during this project. Innovative collaborative strategies supported by the development of e-learning communities will make possible the cooperation between educators and teachers during and after the end of the face-to-face courses.

Finally, the project results and all the experience, that we expect to gain in the project, will be used for the long-term improvement and renewal of the education methods implemented by our institutions regarding the technology-enhanced learning. The planned dissemination activities are also expected to contribute to a long-term exploitation of the project results by educational institutions, authorities, policy-making bodies, unions and networks that will become aware of them for integrating computer-based robotics in teaching and learning and transforming their teaching/learning environment towards constructivist learning.

Conclusions

Robotics is a growing field that has the potential to significantly impact the nature of technology and science education at all levels, from primary to graduate school.

- So far robotics has been introduced mainly in departments of engineering at university level.
- Last few years several attempts have been made in international level (our countries included more or less) to introduce robotics in secondary school education mostly in science and technology subjects.

Although the role of teacher is crucial for the successful introduction of robotics in classrooms, only few projects have been undertaken to train school teachers in using this, completely new for them, technology.

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. So, TERECoP project is expected 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.

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