TEACHER TRAINING IN THE SCIENTIFIC FIELD THROUGH ROBOTICS ACTIVITIES: SOME EXPERIENCES FROM ITALY & SPAIN.

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Abstract

Since December 2006 the authors have started to work with five other partners -Aspete (Greece), IUFM (France), UP-RO (Romania), CUNI (Czeck Republic), 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.

In this work we present some relevant results of 4 concrete actions (pilot training courses, discovery film and First Lego League) that have been carried out in Italy and in Spain.

Keywords
Educational Robotics, Scientific Education, Problem Based Learning, International projects

1. Introduction

For the last two years we have been working on:

- developing a methodology of innovative collaborative strategies supporting social constructivist teaching and learning, applied both in the teacher courses and in students' teaching and learning.
- Selecting and organizing 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.

Then we have started testing and evaluating the practical implementation of the selected tools both in training courses and in real classrooms situation (by the trainees).

In this work we present some relevant results of 2 concrete actions (pilot training courses) that have been carried out in Italy and in Spain. Both activities had a “second part”, respectively the Discovery Film 2008 in Rovereto and the First Lego League (FLL) tournament in Pamplona.

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 north Italy.
The second course was held in Pamplona, where several institutions were collaborating to organise it. The Public University of Navarra, the Supporting Centre for Teachers of Navarra (CAP) and CEIN (Public company which one of his activities is to promote creativity and innovation among young students) made it possible.

In this work we present an analysis of the results and how these two courses are opening new issues in the use of robotics as a learning tool at several levels.
We also give some insights of how finalizing and evaluating robotic-enhanced projects as the result of the evaluation phases of our work as teacher trainers

After every course every partner has organised one open activity, where secondary level students (with their teachers) showed how they are using Robotics at school; is the case of an open day for Educational Robotics at Discovery film 2008 or the co-organisation of the FLL tournament in Pamplona (as part of the Spanish national qualifications for the international FLL).

The structure of the paper is as follows. First we outline the main theoretical ideas and methodology behind our work. Then we describe both courses, discussing some of the results. After that we describe both activities carried out after the courses. Finally we present some conclusions.

2. Theoretical background and methodology

2.1 Learning strategy

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) [1]. 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) [2] [3], is a natural extension of constructivism and emphasizes the hands-on aspect. Vygotsky's (1962) [4] 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 behaviour. 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.

2.2 Methodology

Then 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.
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 [5] [6].
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.

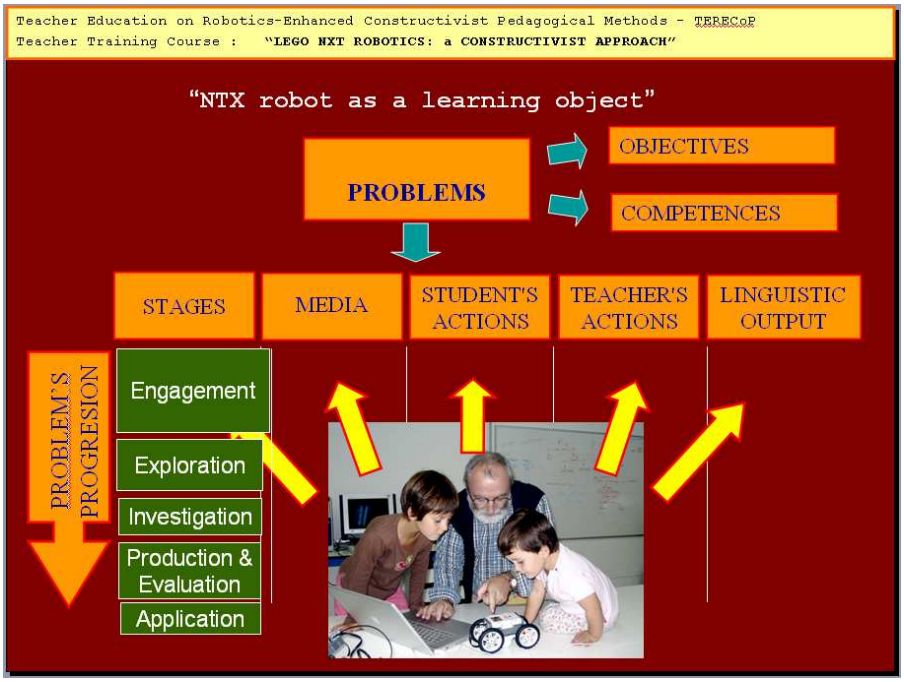

Fig. 1. Slide extracted from the material of the courses

2.3 Technology

We considered different robotic platforms that could fulfil these requirements:

- Several programming paradigms & levels
- Many degrees of complexity (to be able to use it in no university education levels, for example)
- Simple but significant extending possibilities (more sensors, hardware, interface, high level behaviour using AI techniques maybe using a PC as "remote brain" to provide more computational power to the robot, physics and maths simulation, data logging, etc….)

Our final choice was the NXT LEGO technology, because it fulfils the previous requirements and moreover it is possible to start working with it almost immediately (no electrical or other hardware or software arrangements are necessary). Another advantage of the NXT LEGO technology we are interested in is the different programming languages and programming environments available. For instance, with the NXT LEGO is possible o use the original LEGO graphical programming environment NXT-G, or the C-like NXC or the Java based LeJOS-NXJ (some of them requires firmware replacement). Moreover, one has the possibility to use several operating systems and/or platforms(URBI, Universal Real-time Behaviour Interface, for Windows, Mac OSX, Linux or NXT-Symbian running on Symbian 6.0 Java-enabled mobile phones).

3. The pilot courses within the TERECOP project

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. For more information you can refer to the web site (http://www.terecop.eu/) or to [7].
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.

In Italy and Spain these courses took place in November 2007 and April 2008. In both cases, the "trainers" were the partners of DEI (Univ. of Padova, Italy), UPNA (Public univ. of Navarra, Spain) and Rovereto Museum (Italy), and the "trainees" were (mostly) in-service teachers from secondary education level.

The courses aimed 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

The work was oriented to build 'intelligent' machines to be controlled, following all the steps of the construction, from the design to the realization, using a trial and error methodology, but with clear objectives; moreover educational paths were 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.

3.1 The course in Rovereto

The Town Museum of Rovereto has an educational section which organizes educational activities and training courses for teachers. One of the three TERECoP pilot training course were organized by the Italian and Spanish partners of the Project in collaboration with the educational section of the museum. The course started in October 2007 and finished in December of the same year.

3.1.1.- The trainees

The Town Museum of Rovereto had developed, during 30 years of educational activities, a network of contacts with schools which allowed the creation of groups (like *Scienzeonline*)of teachers in service, coordinated by the educational section of the museum, who work to design and implement activities based on laboratories or projects.
So the teachers to be taught, 15 "trainees", came from schools in Trentino and Veneto (two northern regions in Italy) and were all in-service science teachers, 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 group *Scienzeonline:* these were the first to join and then have involved their colleagues in the second group.
The evaluation questionnaire proposed to the trainees at the end of course underlined the great motivation that characterized all the participants.

Interested in the subject	100 %
Trust for the trainers	36,4 %
Interested in the type of conduction	27,3 %
Interested in the goals	72,3 %
Others	18 %
(Curiousity for robots)	
(Relation between the course and the questions of actual teaching)	

Tab. 1. Motivations of the trainees to follow the course

During the course we tried to divide the trainees into heterogeneous groups especially in terms of skills in using robots in order to create profitable partnerships and synergies within the individual teams.
The proposed course is 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 official recalls (in November and in December) and also a weekly consultancy were planned in order to allow the trainees to interact with the Project Terecop trainers during the experimental steps, whereas the Discovery Film Festival 2008, with its usual section dedicated to educational robotics, hosted demonstrations and results of the project based school activities that followed the training phase.

3.1.2.- Carrying out

The concrete objectives of the course were:

- 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.

Follows the table of activities.

Activities (over a total of 30h)	number of 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

Tab. 2. Activities during the course

As you can see in the table, about 16 hours were dedicated to practical activities and discussion about their implementation in classrooms in constructivist/constructionist way.
To the total of 30 hours we thought it would be useful to add a weekly consultancy. In fact the trainees could meet some trainers every wednesday for two months (February and March). We registered that this service was requested for a total amount of 12 hours.
This service helped a group of teachers of the local Scientific Secondary School to improve their technical competences, so thus they installed a laboratory of educational robotics and could present their first project at Discovery 2008. During this festival organized by the Town Museum of Rovereto was also present the project realised by the another trainee of the TERECoP training course in service at the Technological High School.

3.1.3.- Evaluation

The implementation of educational activities enhanced on robotics in the classrooms of two groups of trainees was only one of consequences of course, in fact 5 other scholastic institutions asked to the museum for to be helped to realised laboratories of educational robotics.
These facts were a useful feed-back of our training activity. But to have an evaluation of the course, after the last lesson the trainees made a questionnaire and participate to a group interview. In this paper we chose to underline some interesting topics resulting from the evaluation phase:

1. At the end of the 30 hours a good quantity (66,7%) of trainees thought to have learned very useful things for science teaching. The other part thought to have learned enough useful things.
2. More than the 80% of the trainees thought that the materials, the contents and the activities of the course in general had improved their teaching.
3. In a list of 6 abilities/competences those could have been improved during the course, the trainees chose principally:
    - Application of computer and technology in problem solving
    - Experimental data acquiring
    - Ability in using interfaces and sensors

The last two topics are technical abilities related to a conception of the educational laboratory as a practice of procedures finalized only to verify theoretical laws. Only the first one shows an innovative methodological conception of the laboratory. Maybe during the course the importance of the project based learning was not enough emphasised.
During the group interview the trainees put the attention also on the hour amount dedicated to the practice. They all agreed with the fact that they needed more time to familiarize with the LEGO Mindstorms kits to be able to design and implement educational activities based on robotics in their classrooms. In fact the museum proposed the weekly consultancy to allow them to improve their technical competence in robotics. We have just told about the results of the consultancy, but the educational section of the museum has the strong conviction that the greatest obstacle for the implementation of robotic educational activities in school classrooms are the methodological competences not the technical ones.
From this first experience we learned that in the designing of future teacher training activities it would have been better to get more attention to the methodological question.
In 2008 the educational section of the museum was requested by the school authority of Bolzano (a town 70 km at North of Rovereto) to organize a training course in educational robotics for teachers in service at the secondary school.
The course was implemented in the last part of 2008 with the collaboration of all the members of Italian-Spanish team who designed the one of 2007. The practical activities were very similar to the ones of the first edition, but the group of the trainees was more homogeneous for their starting know how, and every group was under the assistance by an expert leader chosen in the group of the trainers.
We think that this innovation and the more experience of the trainers after two editions of the TERECoP course could have contributed for more results. In fact 4 trainees started to design and implement educational activities enhanced on robotics and on project based learning. The 4 works will be probably presented on May 2009 during Discovery.

3.2 The course in Pamplona

The second course was held in Pamplona, where several institutions were collaborating to organise it. The Public University of Navarra, the Supporting Centre for Teachers of Navarra (CAP) and CEIN (Public company which one of his activities is to promote creativity and innovation among young students) made it possible.

3.2.1.- The trainees

Among the participants we had 11 in-service Secondary school teachers from Navarra and 3 teacher students from UPNA

Within the attendees the average is twenty years in-service at secondary schools. Nine are teaching technological subjects and other two not technological teachers, French and English language teachers (who drop out after the first session). This means that most of the attendees were teachers

with a lot of experience but, due to the dates of the course, not many young teachers were interested (most of them had an official public exam in june)
These teachers basic background is on science or engineering careers.
The main motivation aspects of the course have been the theme and the proposed methodology.

Fig. 2. Trainers & Trainees

3.2.2.- Carrying out

The main features of the course were:

- 30 accredited hours (12 hs face to face sessions, 6 hs not face tutoring, 12 hs freelance work in own centres).
- Use of a virtual platform, e-class to leave training materials to be used by the trainees as: tutorials, schedules, presentations, etc. It was also used for communication purposes between trainees and also with teachers: exchange of messages, presentations, and materials…
- We made a didactical guide in Spanish for this course in two parts. The first one includes the theoretical foundations of our constructivist approach. The second one is a sequence of problems designed to be done during the course. In the next months, we will make a definitive version and it will be translated into English.
- During the course, we had in mind that most of the teachers are going to participate into the First LEGO League to be held in Pamplona in november 2008.

To reach the main course objectives, the contents and activities promoted the following topics:

- To discuss the basics of constructivism/constructionism in specific environments with robotics.
- To acquire basic skills in the design, construction, programming and educational use of robots.
- To acquire skills for designing and tutoring interdisciplinary projects in the field of robotics education.
- To promote within students in aspects like "Learning to Learn", "cooperative working team" and "Learning to undertake projects and to solve problems".

3.2.3.- Evaluation

To evaluate the acquired knowledge and competences, we used:

- Informal group discussions (at the end of every face to face session),
- Tests,
- Video recording,
- and weekly face to face individual consultancy.

We have observed that the great interest is on working with the constructivist theory, PBL methodology, working in groups and designing, constructing and programming robots. Nevertheless, when we were proposing the use of robots to learn other things, most of the teachers were not completely open as they have doubts about the utility of this type of teaching.
It has been very interesting to have a mix of teacher in the course: teachers in service, university teachers, foreign university teachers from Italy and future primary school teachers.
As well as to work with teams of teachers from the same school, which has given a reality point to the future plans of use of this robots.

The contents and the teaching methodology have ensured the expectations on the theoretical, technical and practical questions of the course.
Teachers think that there was an important interaction between trainers and trainees, in some cases there was not enough interaction between trainees and trainees.
All of them think that the contents and the methodology are significant add value for teaching, but they are not completely sure on how to use this for science teaching or in their daily teaching activities.
They have expressed their agreement with the proposed didactic contract and most of them have highly meet their expectations, even some of them have asked for a continuous training in this matter which we will provide during the coaching for the FLL.
For his part, CEIN (European Centre for Innovation in Navarra) was already planning to organize at the end of 2008, and in successive years, a tournament at regional, state and global levels, for teams of students (tutored by a teacher or "Coach") who are working on robotics projects and for whom this teachers training course would give them an special preparation.

4. The "external" activities

In both cases and taking advantage of local partners related with science dissemination, we decided to "test" the acquired "know how" of our trainees in these two events we describe within this section.

4.1 Discovery film 2008

In the days May 29th-31st, 2008 the town Museum of Rovereto organized the 8th 'Discovery on Film', the annual festival of the scientific and technologic film with a very significant section dedicated to robotics. The festival was held at the main site of the Museum, occupying the entire ground floor for stands and exhibitions, and the conference room for meetings, presentations and film showings (Fig.3).

Fig. 3. Discovery 2008: the stands and the conferences room

Apart from some stands held by commercial (e.g. E-motion, presenting for the first time in Italy Pleo, an interesting dinosaur-like robot, see http://www.pleoworld.com/) and research entities (such as the University of Verona, presenting a soccer multirobot application, and the School of Advanced studies S.Anna in Pisa, presenting an European project for producing a autonomous robot for waste management, see http://www.dustbot.org/), most of the other stands have been organized by schools of different grades involved in robotic activities. Among those presenting Mindstorms-based experiences (both RCX and NXT), two stands presented works suggested by teachers following the TERECoP course implementation of Rovereto, the Liceo Ginnasio 'Rosmini' of Rovereto , presenting a robot for variable motion study, and the Technical Industrial Institute 'Marconi' of Rovereto, presenting a multirobot application for playing 'tic tac toe' (Fig. 4).

Fig. 4. Discovery 2008: The "Tic Tac Toe" NXt robot

4.2 First Lego League 2008-09 in Navarra

The FIRST Lego League (also known by the acronym FLL) is an international competition for elementary and middle school students (ages 9-14 in the USA and Canada, 9-16 elsewhere).

Each year the contest focuses on a different real-world topic related to the sciences. There is a scientific project related to the topic of the year to be developed and presented. The robotics part of the competition revolves around designing and programming Lego robots to complete tasks. The students work out solutions to the various problems they are given and then meet for regional tournaments to share their knowledge, compare ideas, and display their robots.
Teams are allowed to only win one of the awards shown at Fig. 5. In this figure it is also possible to see the different parts of the tournament and the different stages and juries involved.

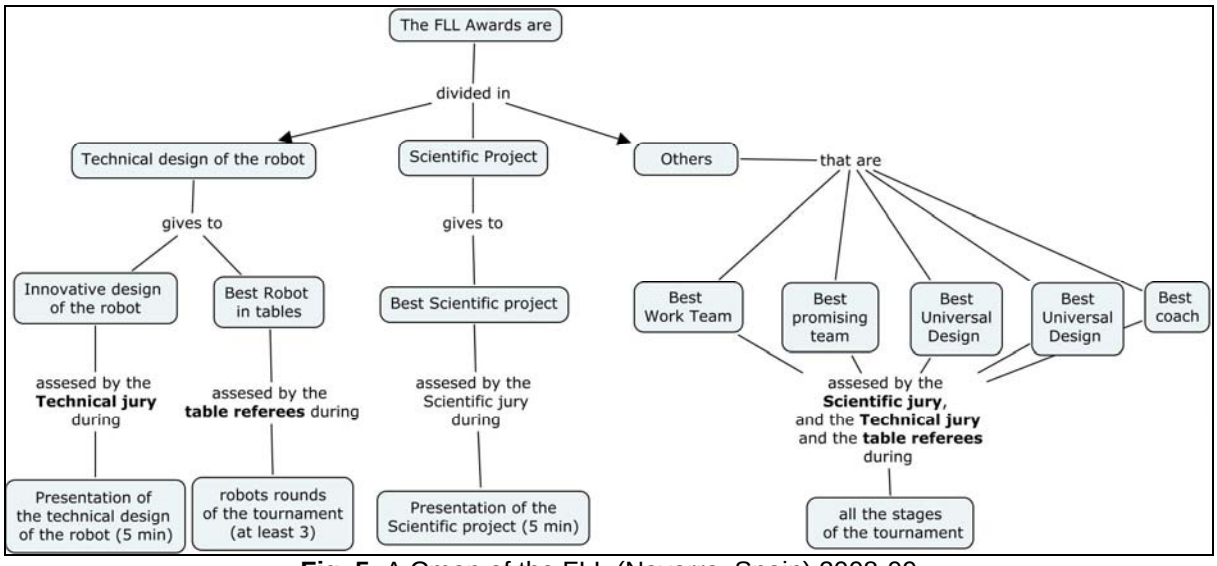

Fig. 5. A Cmap of the FLL (Navarra, Spain) 2008-09

15 teams from Navarra and 1 from Zaragoza took part in the first edition of the International First Lego League in Navarra that was done in November 2008 (previous round before the Spanish final of February 2009).
This year the challenge focuses on the earth's past, present, and future climate. Students must research a climate problem occurring in their area, find a solution, then share it. They also have to research another area which has the same problem as their area.
The robot is autonomous and completes missions on a mat where the missions are set up (see Fig. 6). The robot then has two and a half minutes to complete those missions.

Fig. 6. At the FLL tournament

5. Conclusions

These trainee's courses are 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, either in a formal learning context or in an informal learning context.

It is very difficult to include such approaches within the current curriculum in the schools, it not only needs a lot of time but also a change on the official curriculum of each country. Another difficulty is that a great investment is needed to start up

The two activities, Discovery and FLL, showed us what can happen with educational activities carried out at school and used out of the school.

6. Acknowledgements

This paper was partly based on work done in the frame of the project "Teacher Educations on Robotics-Enhanced Constructivist Pedagogical methods" (TERECoP) funded by The European programme Socrates/Comenius/Action 2.1, Agreement Nº 128959-CP-1-2006-GR-COMENIUS-C21 2006-2518/001-001 S02.

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