Teaching with robotics: different experiences at school after the TERECoP courses

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Abstract

At the end of the TERECoP (Teaching Education on Robotics Enhanced Constructivist Pedagogical Methods) Project, some Italian partners have gone on introducing some educational activities enhanced on robotics in science teaching in the schools of the region Trentino-Alto Adige. After the first pilot training course in Rovereto in 2007, they set some other training courses based on the TERECoP standard. The teacher-trainees of these courses made some experiences of teaching Science, Physics, Maths, Logics using robotics working in a constructivist way. The authors report three very different experiences for environment, resources, available times, students and teachers involved. They reached some interesting results in every experience; many of them are common even if the starting conditions were different.

Introduction

In October 2007 in Rovereto occurred a TERECoP (Teaching Education on Robotics Enhanced Constructivist Pedagogical Methods) pilot training Course, which had the goal to prepare teachers to use activities enhanced on robotics based on the constructivist theory in their lessons. Another course followed the first one in Bolzano in October 2008. Some teachers-trainees and some experts of the section of educational robotics of the Town Museum of Rovereto worked on some educational activities enhanced on robotics from 2008 until May 2010.

This document is structured in three parts: it begins with a description of the experience realized by a middle school in collaboration with the Museum of Rovereto with a brief introduction on the school and the new LEGO Education Centre of the museum. The second part speaks about the experience of a school in Bolzano where teachers and pupils organized a club where pupils could work together on projects of a certain difficulty. The final part is a report by a teacher of Rovereto who met the educational robotics three years ago and now is one of the most active experts in our area.

At the end of the TERECoP project in Rovereto teachers and researchers of the Museum formulated some questions:

- How can we realize educational activities enhanced on robotics in a constructivist way every year?
- How can we promote them to involve other teachers and institutions?
- Which developments and improvements can have this way of working?

For the first question a researcher of the museum and some teachers of the middle school tried to answer organizing some curricular activities using robotics. The goals were different:

- Verify whether robotics enhanced activities could really help to learn.
Proceeding by attempts and errors to structure learning activities enhanced on robotics. This group thinks that it could be interesting to create a repository of activities to implement in medium classes that could be used and improved by all the teachers.

Let the teachers construct a know-how to be autonomous in organizing their educational activities enhanced on robotics. In fact, just after the TERECoP course, a relevant part of the trainees needed anyway assistance by the researchers of the museum to introduce robotics in their classes, but they could gradually become autonomous.

The Scientific High School of the Salesian Rainerum Institute

The third one is the experience realized in Bolzano, in a high school were some teachers involved in TERECoP courses set a LEGO Education Centre and two others laboratories for educational activities enhanced on robotics.

The European Scientific High School of Bolzano is run by the Religious Congregation of the Don Bosco Salesians whose commitment is to enable a sane development of young people through school education and the organization of free time activities.

Being a Catholic school the educational choice goes far beyond conveying knowledge; its goal is to support its students in becoming caring, upright, responsible and well-educated citizens.

Certainly a school has the duty to “teach” the official curriculum, but this school refuses to reduce its vocation to the mere transmission of intellectual knowledge and skills. Metacognition, values, interdisciplinary teaching, student protagonism are key words of its POF (piano dell’ offerta formativa = educational and didactic outlines).

Interclass Project: Seminars and Laboratories

Among various other choices the Rainerum high school has made, there is the purpose to draw your attention to our seminars and laboratories in which students of different classes/ages work together.

This project started as an experiment more than ten years ago as optional activities the school offered in the afternoons, intended to meet the explicit students’ need to DO something, to conquer their know-how rather than being fed, to work on something concrete. Teachers, on the other hand, felt the urge to experiment new teaching techniques like peer-teaching, team-work, cooperative learning, problem solving.

Seeing the success of these extra-curricular activities, the school council decided to transform 15% of the curriculum (by Italian law under the responsibility of the single schools), introducing this new teaching into the ordinary lesson plan. Students of the last three years also choose three seminars, but just one scientific laboratory, which lasts from September to June, to enable them to do some “real” scientific research. One of these laboratories is dedicated to Robotics.

Because of these characteristics, in 2008 some partners of the TERECoP project organized a training course for teachers in service set on the TERECoP model. Some teachers of Maths, Physics and Technology attended it.

The robotic club at the Salesian Rainerum Institute

Since 2003 inside the Robotics laboratory a group of pupils and teachers constitute a club which uses the rooms of the school to realize advanced robotic projects.

The teachers believe that the participation of the students to this club could develop their abilities in problem finding, problem solving, projecting solutions, cooperating in the respect of the contribution of each member. Besides they think that working on the solutions of robotic problems could take the students to apply (and understand) some knowledge met in the curricular lessons and stimulate them to construct new knowledge and skills to solve the problems.

The technical coordinator is a student, generally at the last two years of high school, and all the group decides the project they will realize in the following two years.
The teachers during the curricular lessons give problems to solve and treat subjects to help the pupils to construct the know how to realize the project. During the activities of the club the teachers help the pupils to divide a great problem in many sub-problems.

**The Eu.R.Ex Project**

A good example of this way of working is the realization of a system of cooperating robots for the mapping of an area without using Gps. You can find in the Table 1 the list of the activities those are classified in curricular and club, and by great class of problems. In the curricular activities they used only LEGO Mindstorms, in the club they used Mindstorms and they built some structures and chose some hardware to programme using C/C++, BasicX.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Class of problem</th>
<th>Curricular, Club</th>
<th>Actions of the teacher</th>
<th>Actions of the students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creation of a robot which poses itself orthogonal to a wall</td>
<td>Positioning</td>
<td>Curricolar</td>
<td>Gives the problem and discuss the strategy proposed by the pupils. Proposes a strategy</td>
<td>Propose strategies together, built and programme the robot</td>
</tr>
<tr>
<td>Robot moving along a wall</td>
<td>Positioning</td>
<td>Curricolar</td>
<td>Gives the problem and discuss the strategy proposed by the pupils. Proposes a strategy</td>
<td>Add the necessary sensor and write the programme.</td>
</tr>
<tr>
<td>Robot which can reach one angle in a room</td>
<td>Positioning</td>
<td>Curricolar</td>
<td>Gives the problem and discuss the strategy proposed by the pupils. Proposes a strategy</td>
<td>Propose and discuss strategies together, built and programme the robot</td>
</tr>
<tr>
<td>Robot which can circumnavigate an obstacle and going on following its original path.</td>
<td>Positioning</td>
<td>Club</td>
<td>Coordinate the discussion between the members of the club.</td>
<td>Propose and test solution. Discuss the results and the proposals.</td>
</tr>
<tr>
<td>Make a robot to communicate numbers or strings to other ones using bluetooth</td>
<td>Communication</td>
<td>Curricolar</td>
<td>Shows the tools of the hardware of LEGO Mindstorms.</td>
<td>Try to realize simple programmes to take robots in communications</td>
</tr>
</tbody>
</table>

Table 1: phases of the construction of the knowledge to reach the goals
<table>
<thead>
<tr>
<th>Task</th>
<th>Curriculum</th>
<th>Clement</th>
<th>Make the programme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robot which measure a length and communicate the data</td>
<td>Communicat</td>
<td>Help the pupils to find a strategy</td>
<td></td>
</tr>
<tr>
<td>Co-operating robots to measure lengths and temperature and communicate each other the data.</td>
<td>curricol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programme a robot to move in straight lines along a wall and turn making right angles when it finds obstacles</td>
<td>Mapping</td>
<td>Discusses a strategy to make the robot knowing its position only using the encoders.</td>
<td>Propose strategies and test them discussing the results.</td>
</tr>
<tr>
<td>Programme the robot to record its position and the ones of the obstacles on a file.</td>
<td>Mapping</td>
<td>Guide the pupils in the discussion</td>
<td>Propose and test solutions and discuss the results.</td>
</tr>
<tr>
<td>Projecting the system of cooperating robots</td>
<td>Cooperation</td>
<td>Divides the pupils in groups. Divides the great problem in many sub-problems. Looks for funds and helps the student coordinator to regulate the expenses.</td>
<td>Discuss on the hardware and software to use, and each group propose its solutions to its sub-problems and propose the materials to buy.</td>
</tr>
<tr>
<td>Realizing the rovers and the programme</td>
<td>Cooperation</td>
<td>Help the pupils to find information and to construct their know how, helps the student coordinator.</td>
<td>Construct themselves the know how, the most expert student teach to the less expert. Try to realize the</td>
</tr>
</tbody>
</table>

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The curricular lesson was set on two hours a week in the afternoon, the club worked after the curricular lesson until 7 p.m. and during another entire afternoon.

The teacher of robotics is also a member of the club and he decided to work on the positioning because he thought that this work could help the pupils to apply and better understand some questions of the Cartesian geometry and on the minimum of functions and approximation.

He tried to proceed creating a non-equilibrium situation giving a problem to bring the pupils to construct the knowledge to solve the problem and come back in equilibrium.

The students of the curricular group (21 divided in groups of 3) just knew the basics of the NXT-G programming and had the know-how to realize robots equipped with sensors. So they worked to realize a robot who could reach every angle of a rectangular room starting from a random position in it.

The first step was to make a turning robot to reach the next wall and place itself parallel to it. After discussions between pupils they agreed with the teacher that a good solution could be programme the robot to pose itself orthogonal to the wall.

The most chosen strategies were two:

1. put two distance sensors on the front part of the robot and make the robot to pivot until the two sensors detect the same distance
2. put only one distance sensor on the front and detect the distance until it reaches the minimum value.

The second one was finally chosen because it allows to use less sensors and leaves the possibility to use the input port for another device, and also because it opened a question in which they could apply their knowledge of geometry. In fact the segment of minimum length joining a point to a plane is perpendicular to the plane.

The pupils had to find the best algorithm to approximate the value of the minimum distance.

After the solution of this problem the next one was to make the robot moving along a wall checking the distance with a lateral sensor pointed to the wall. They proposed to use the distance sensor and the robot move keeping itself near the wall correcting its trajectory that becomes a serpentine.
So the robot finally could reach any angle of room self positioning in an orthogonal direction respect the wall and turning of a right angle when closed to it, than it moved along the wall until the next angle. During the activities of the club the pupils realized a robot with only one distance sensor posed on a turning structure so thus to be oriented in the direction they want to check. They tested an algorithm to circumnavigate an obstacle like a column and come back going on moving along the wall. The robot checks the distance at left (near the wall) and in front of it, until it detects an obstacle. Then it rotates on itself of 90° and goes on until the detected distance at the left becomes bigger than threshold. Than they turn left and repeat the loop, at the second time it turns right finding itself oriented again along the wall. The second step was the communication which was solved using the Bluetooth tool of the Brick of the Mindstorms. Finally the pupils found the strategy to make two robot cooperate: the first one goes straight to measure a corridor, then comes back and moves again with another one with a light sensor to detect the lateral rooms and a temperature sensor. At each room the second robot stops, sends a message to the first one which stops too. The second one goes into the room and records the temperature on a file, so they move again straight on until the next room. The first robot which knows the length of the corridor, sends the message to stop to the second one because they’re at the end.

Using the strategy of turning of 90°, the robots could simply know their coordinates every step; in fact going straight on the robot increases only the X coordinate, turning right or left and going straight on for a step the robot increases or decreases only the Y coordinate.

At this point the students of the club were ready to realize their project. The last one was a robotic tourist guide, so it was necessary to create a map of the area: the work needed a lot of time. So they decided that the following project would be a mapping autonomous system. Seeing that some particular animals were more efficient than the human beings to solve some kind of problems, they decided to adopt a specific model of cooperation. They also worked with the Philosophy teacher to acquire a method to classify social systems, in fact they could...
characterize an efficient social system with the adjective “eusocial” which means “good (eu) social”. They were finally inspired by the bees to set their system, and they decided to build a system composed by many cooperating robots to increase the efficiency. The coordinator student and the teachers thought it was better to test some parts of the final project using LEGO Mindstorms robots, because the budget was limited to 4000 € and the group had to choose the materials to buy very carefully. So one group of pupils began to realize and programme three rovers. They used NXC (Not Exactly C), a language very similar to C, the language of the final products. The rovers were a two motors belted structures, had a distance sensor that could be oriented by a turning structure moved by a motor, and a compass to check if the data coming from the two encoders were correct. The final version realized in metal has also a webcam that can be used to recognize objects previously defined (for example to localize entrances). Finally they realized three rovers (worker bees) in wi-fi communication with a computer (queen bee) which receives and stores the data into a common database. The central unit is able to transform in real time the different values into coloured maps of the explored area. The central PC also coordinates the work of rovers; it decides, for example, in which direction each robot has to go and could change the role of every rover whenever it finds it’s necessary (for example because of problems for one of the explorers). The users could access to the system using a simple web interface that permits to send different commands. The entire project is made using open-source software, in order to permit a personalization according to the needs.

Results and conclusions

Three teachers and eighteen students (from fifteen to nineteen years old) were involved in the project for two years (around 400 hours). Were reached the following goals:

• The students worked on a real problem and faced the complexity of the physical world, that required to use and construct multidisciplinary competences.
• The pupils realized the project working in teams and learning to cooperate between individuals and groups, to discuss solutions, test them, and proceed by attempts and errors to reach the best solution.
• The pupils worked constructing themselves knowledge and skills to solve the problems
• The students improved their knowledge not only in robotics but also in Maths, Physics, Biology and Sociology.
• The project participated at two contests where the pupils had to set demonstrations, explanations and had to answer to questions by experts from universities in English and German, so we can say that they improved the skills involved in these activities.
• After the participation at the project all the students increased their marks in more than one of the subjects involved, also the pupils those had bad results in Maths and Physics.
the two students of the last year at the final exam had results over the level they kept the years before, so sensibly over the expectations especially in Physics and in the oral test where they had to use their skills on explaining, demonstrating, arguing, inferring.

- The project and all the robotics activities at Salesian Rainerum Institute in the last two years created a resonance so thus other schools are in touch with it to enhance some of their educational activities on robotics. There is a little correlation also between the activities in Rainerum and the statement by the School Authority of Bolzano to insert Robotics in the curricular subjects in every Primary and Middle school of the area.

Open questions

The main open problem was nowadays the evaluation of the activity, in particular to quantify the real learning of the pupils. We can affirm that an improvement of their general preparation and an increasing of their marks was detected, but we cannot know which skills each student has developed and we cannot measure how much knowledge he got.

The teachers are working on schedules those allow them to evaluate the knowledge of the pupils by the application of it during the work sessions and some skills like problem solving or create cooperative relationship with the other members of the group.

The museum of Rovereto

The Town Museum of Rovereto represents an interesting and tested reality of Rovereto. It is active on a large variety of areas of considerable complexity. It works with attention to the territory on subjects like pollution, the study of the environment, flora, fauna, astronomy, archaeology, historical-artistic heritage of the city, data and materials archiving, teaching. The educational section has always provided a counselling service, as a place to find information, as a creator of educational materials and work units, as a facilitator with respect to schools, as an organizer and promoter of research groups. Many of the interventions promoted and achieved have always been implemented in close collaboration and sharing with those people who daily work in the Museum and other cultural institutions in the territory.

Without claiming to replace normal school paths with external proposals, the Museum aims to strengthen and enrich school planning by providing a service that can improve the professionalism of teachers. The educational department believes that with these activities it’s possible to find a proper place in the proposed development of the model of education in the local territory, providing methodological innovation, improving and supporting new models of training (workshops, laboratories, consulting, research projects). The use of information and communication technologies is a necessary step, so that all experienced and new teachers should be given the opportunity to acquire basic skills in this area.

The proposal of the Museum in robotics is investing both lab activities and stages for schools, and teacher training. For students robotic laboratories are offered in Museum’s structures in the morning or for an entire day: during these activities the class with its teacher has the possibility to know how to work with intelligent machines and finally build robots. Moreover the educational section organizes and manages four month long modules on robotics conducted by Museum operators at the requiring school once a week in cooperation with the class teacher.

For teacher training the Museum organizes every year a workshop inside the festival of the scientific and technological documentary “Discovery on film”. This year in the Museum a LEGO Education Centre was created, where teachers, kids and families could use the Educational LEGO kits, especially the Mindstorms ones, to teach or learn.

The collaboration between the museum and the school of Vezzano

In the first part of the year 2008/2009 a teacher of technology of the middle school of Vezzano, a little town in Trentino, asked for the collaboration of the robotic section of the Town Museum of Rovereto, because she had already met some members during the
TERECoP course that she had begun to attend. The school thought to prepare some educational activities enhanced on robotics to teach some subjects related to automation buildings and bridges. The goals were:

- Use robotics to correlate knowledge of physics, maths, informatics and electronics to study technology.
- Introduce the most important concepts of the Boolean logics and programming.
- Work on problem solving in a constructivist way.

The course was structured in ten lessons of two hours each. In every lesson was given a little problem to increase the knowledge of the pupils in order to take them to elaborate the solution of the main problem. For this reason the lesson was divided in two parts. The first one (around half an hour) was dedicated to a theoretical explanation of the problem and to the introduction of some concepts they needed. In the second part the students were divided in groups and they worked to build and program the robot to implement the solution theoretically elaborated before. At the end of the course we reached the following goals:

- The pupils improved their knowledge not only in robotics but also in curricular subjects like maths, physics, and so on.
- They improved their skills of problem solving thanks to the questions given to the students during the lessons.
- A very important result was that the following year the teacher was able to propose again a similar experience and she realized it alone without the help of the Museum. A critical point was related to the realization of bridge and buildings. So we preferred to build some simpler structures, for example rovers equipped with sensors. Those robots moved and analyzed the environment.

Table 2: phases of the work

<table>
<thead>
<tr>
<th>Lesson n.</th>
<th>Goal</th>
<th>Percentage of theoretical explanation</th>
<th>Percentage of empirical work</th>
<th>Open questions</th>
<th>Argument</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introducing kit and robotics</td>
<td>80,00%</td>
<td>20,00%</td>
<td>What is a robot</td>
<td>Robot's language: binary</td>
</tr>
<tr>
<td>2</td>
<td>Programming - Handling of the robots</td>
<td>50,00%</td>
<td>50,00%</td>
<td>accuracy in covering spaces and of changes of direction</td>
<td>The meaning of programming - The compiler</td>
</tr>
<tr>
<td>3</td>
<td>Interfacing of touch-sensor</td>
<td>50,00%</td>
<td>50,00%</td>
<td>Change robot action in function of touch-sensor's state</td>
<td>Boolean logic</td>
</tr>
<tr>
<td>4</td>
<td>Interfacing of more than one sensor</td>
<td>50,00%</td>
<td>50,00%</td>
<td>Change robot action in function of more than one sensor</td>
<td>More task: serial/parallel use of sensors</td>
</tr>
<tr>
<td>5</td>
<td>Display sensors values</td>
<td>50,00%</td>
<td>50,00%</td>
<td>Change robot action with a display debug</td>
<td>The problem of the memory (Flip-Flop) - Variables</td>
</tr>
<tr>
<td>6</td>
<td>Competition</td>
<td>0,00%</td>
<td>100,00%</td>
<td>Finalize own robot for discovery</td>
<td>-</td>
</tr>
</tbody>
</table>

One more facts: robotics' experience in high school ITI G. Marconi in Rovereto.

Before the conclusions we thought to report some notes by one teacher of a Technical High school in Rovereto. He was a trainee of the pilot TERECoP training course in Rovereto in 2007 and he has become one of the most active teachers in educational robotics, he was trainer in the course in Bolzano and currently holds two courses in our region based on the Proceedings of SIMPAR 2010 Workshops

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TERECoP training course. This could be considered another fact to evaluate the results of the TERECoP Project and the dissemination of educational activities enhanced on robotics.

“In this short issue I'm going to make some points about the introduction of the educational robotics during the academic year. I am a teacher of information and communication technology and in 2007 I attended a course of robotics managed by a TERECOP's team. That was the first opportunity to learn what the Robotics is and what the Educational Robotics allow to do. With the support of TERECOP's team I planned an educational activity with the third class of the Scientific and Technological High School. The main goal of that activity was to introduce the structured programming by educational robotics to the pupils. I needed to find a new approach to teach that complex subject. During the course I realized that to program a robot in order to do something is easier than to program a computer.

That owe at the fact the robot can do a limited range of actions and at the same time, it's possible to find different solutions in order to resolve the same problem. The students can work starting from different points of view. They can try to find a solution starting from the elementary steps to the complex steps. This approach has known like Bottom-Up strategy in order to get the final solution. Many times this is the easier way to allow to the students to grow-up step by step especially if they are younger than sixteen. After this first approach, they can use the top-down strategy, which is essentially the breaking down of a system to gain insight into its compositional sub-systems. In a top-down approach an overview of the system is first formulated, specifying but not detailing any first-level subsystems. Each subsystem is then refined in a more detailed way, sometimes in many additional subsystem levels, until the entire specification is reduced to base elements or elementary steps.

After the third class I taught Robotics to other classes and I obtained good results. At the end of each academic year the students made several robot's prototypes and with these we attended the Discovery Onfilm exhibition. That exhibition is managed by Town Museum of Rovereto. During the Discovery OnFilm, Students and teachers can share their educational experiences and more over they can acquire new ideas in order to improve their teaching activity. In conclusion, I can sustain that the educational robotics is a great opportunity to involve the students to learn several scientific subjects and it helps everyone to live better the learning processes.”

**General Conclusions**

This three experiences are the testimonials of the great activity created by the introduction of the TERECoP courses at every level of school and of specialization. We can find some general results of everyone:

- The teachers have become able to autonomously enhance activities of educational robotics.
- The pupils often worked in a constructivist way and they increased their knowledge and improved some skills.
- The students improved their knowledge and skills not only in robotics, but in Maths, Physics, Logics, Science.
- The pupils involved in every experience reported realized all the projects working in team and learning to cooperate between individuals and groups, to discuss solutions, test them, and proceed by try and error to the best solution.

The problem of quantify the knowledge acquired by the students is still open. This kind of activities could be a good practice during teaching all matters and could be alternated with the traditional type of lesson.