Teachers as designers of robotics-enhanced projects: the TERECoP course in Greece

Kyparisia Papanikolaou[1], Stassini Frangou[2], Dimitris Alimisis[1]

[1]Dept. of Education, School of Pedagogical & Technological Education, Greece
[2] Dept. of Philosophy and History of Science, Interdisciplinary Program of Graduate Studies in Basic and Applied Cognitive Science, Greece
spap@di.uoa.gr, stassini.frangou@sch.gr, alimisis@otenet.gr

Abstract. In this paper the training course about educational robotics implemented in Greece in the context of the TERECoP project, will be presented and discussed. During the course, trainees worked in a constructionist learning environment and they were actively engaged in activities working in teams with peers. Trainees initially worked as students to familiarize with materials and the programming environment, then they worked as teachers to reflect on a methodology for designing robotics-enhanced activities and the pedagogical implications of working with programmable robotic constructions in the classroom, and finally as designers constructing their own project. To enhance the sense of community and promote collaboration during and beyond the face to face meetings, an e-class was also maintained.

1 Introduction

Research on the implementation of innovations shows that it is not easy to change teachers' behaviour [3]. When designing a teacher training course it is useful to remember the educator's axiom "teachers teach as they are taught, not as they are told to teach". Thus, constructivist professional development sessions should better be based on learning activities that teachers should be able to use in their own classrooms. It is not enough for trainers to describe new ways of teaching and expect teachers to translate from talk to action; it is more effective to engage teachers in activities that will lead to new actions in classrooms.

During the 2nd year of the 'Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods' (TERECoP) project (European Programme Socrates/Comenius/Action 2.1, Training of School Education Staff) [2], six training courses on educational robotics were implemented at the corresponding European countries of the eight institutions that participate in the project. The curriculum of the course and the training methodology were designed during the first year of the project. In particular, the training methodology is constructivist in the sense that focuses on learning experiences to enable trainees to build their own understanding of the technological and pedagogical perspectives of educational robotics. As far as the implementation of the courses is concerned, we adopted a combination of face to face

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meetings with online learning to enhance communication and collaboration among the course participants. However, each national team decided on specific aspects of the training context such as the schedule, the trainees' profile, the activities used through the course.

Especially, the training course implemented in Greece was held at the premises of the School of Pedagogical and Technological Education (ASPETE) in Athens, and organized in 5 face to face meetings of six teaching periods each (5x6=30 teaching periods in total) during 3 Fridays/Saturdays afternoons. In this course participated 4 trainers and 23 trainees who were teachers in service (4 teachers of primary education and 11 of secondary education) and candidate teachers. During the course, trainees worked in a constructionist learning environment since they were actively engaged in activities, working in teams with peers. To enhance the sense of community and promote collaboration through the course an e-class was also maintained. The final products of the trainees, some of them are briefly presented in Section 4, certify the potential of the proposed training methodology and implementation.

Fig. 1. Teachers as trainees

In this paper the training course implemented in Greece will be presented and discussed. In Section 2 the training course, its scope and aims, as well as the way it was scheduled is described. In Section 3 the e-class and the way it was organized and used through the course is discussed. Then in Section 4 the trainees' products are presented. The paper ends with concluding remarks briefly discussing the preliminary evaluation results based on the trainees' products and comments.

2 Training Course: context, contents, and structure

During the training course, trainees undertook multiple roles. They initially worked as students to familiarize themselves with materials and the programming environment, then they worked as teachers to reflect on the methodology for designing robotics-enhanced activities used in TERECoP and on the pedagogical implications of working with programmable robotic constructions in the classroom, and finally as designers constructing their own project.

In particular, the training course was organised in five (5) meetings that each one lasted for six (6) teaching periods of 45 minutes. The course curriculum was organised in the following six (6) sessions each one focusing on a specific theme:

- **Building a 'didactic contract'**: introduction to the course and the theoretical background aiming to agree on a "didactic contract".
- **Theoretical framework** for designing robotics-enhanced projects.

– **Focusing on construction**: Robotics as a learning object focusing on materials.
– **Focusing on programming**: Robotics as a learning object focusing on the programming environment.
– **Focusing on a methodology for designing robotics-enhanced activities:** Designing robotics-enhanced projects/activities based on the methodology used in TERECoP.
– **Trainees' projects presentation and evaluation**: course evaluation was based on questionnaires and interviews.

Below the scope and aims of each session, as well as the materials prepared and used, the activities that trainees undertook and their products, are presented.

Building a 'didactic contract'. In this session the focus is on 'breaking the ice' and constructing a 'didactic contract' between trainees and trainers. Initially the trainers and trainees introduce themselves discussing about their expectations from the course and agreeing on a 'didactic contract'. In particular, the trainers presented shortly themselves and then invited the trainees to talk in groups of 4-5 persons and each one to introduce him/herself in 2-3 minutes to the group. Trainees were asked to provide personal/professional information, to express individual learning needs and goals, expectations and possible learning difficulties. Lastly one representative from each group, shortly introduced the members of her group to the plenary. Trainees and trainers were also invited to post a message in a relevant topic at the discussion forum of the e-class shortly introducing themselves**.**

Then, one of the trainers presented the overall aim, the specific objectives of the course, the content, and the training methodology. The trainees were invited to express their own expectations, opinions, suggestions and ideas first in their groups and then in the plenary through a representative. Trainers and trainees discuss and decide on the 'didactic contract'. The session finished with an agreement between the trainers and trainees on the above mentioned issues and on arrangements necessary for the smooth running of the course. Finally, this 'didactic contract' was uploaded in the documents area of the e-class.

Theoretical Framework. At this session the focus is on the theoretical background of designing robotics-enhanced learning activities. Trainees undertook specific activities involving critical thinking about constructivist and constructionist principles and the role of educational robotics. Initially the trainees worked in groups of 3-4 members and each group studied a specific section of the paper 'Constructivist Learning Using Simulation and Programming Environments' [6].Then, the groups submit an abstract, explaining what they found more important to their particular reading, at the discussion forum of the e-class in a relevant topic that was visible to the whole class. This way all the trainees shared their readings and opinions. The representative of each group presented briefly the abstract to the whole class and the trainers commented on the presentations. Then the trainer presented the basic principles of constructionist learning emphasizing on the use of educational robotics as a leaning tool.

Finally, the trainees completed their diary which was organized around the following questions: (a) What was the best that happened to you today through the course? (b) What was the worst that happened to you today through the course?

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The diaries were uploaded at the private document area of each group in the e-class. Trainees were also invited to comment on their experience of the first training day submitting a message in the relevant topic at the public discussion forum.

Closing this session, the papers entitled ‘Piaget’s constructivism, Papert’s constructionism. What’s the difference?’ [1] and ‘Rethinking Learning in the Digital Age’ [4] were proposed for further reading (they were available in the public document area of the e-class).

Focusing on construction. This session focuses on the introduction of the materials included in the Lego Mindstorms Education NXT kit, and robots’ assembly. It was organized in two sections. During the first one, trainees got organised in groups of 3 or 4 members. The basic criterion for selecting a group was that its members should be able to cooperate through the face-to-face meetings but also during Easter holidays in order to develop their own project. Thus, the group formation was decided by the trainees themselves. One Lego Mindstorms Education NXT kit was given to each group and trainees worked in groups to identify sensors, motors and construction parts like blocks, axles etc. in their kit. A trainer made a brief introduction to NXT functions and then the groups were promoted to experiment with the touch sensor, light sensor and servomotor in order to become familiarized with sensors and their parameters. At the end of this section, a discussion about the technical characteristics of each sensor took place in plenary.

During the second section trainees constructed a car robot with two motors. To this end, they used instructions included in the official guide. They were also proposed to open the Lego digital designer and use it as an additional guide for the construction of the car robot. Lastly, a discussion-evaluation of their experience through the construction of the robot-car took place. The trainers and trainees agreed on a set of criteria for evaluating robotic constructions.

Focusing on programming. The third session focuses on the programming environment and the development of virtual models that guide robots with varying configurations, i.e. motors’ activation using basic programming blocks within the NXT-G software, robots’ assembly in different configurations and development of meaningful programs to control them.

This session was organized in three sections. At the first section, the trainees working in groups undertook specific introductory activities to the programming environment of Lego Mindstorms Education NXT. The initial project was to design a programme that moves a robot along the sides of a square. To this end, an appropriate worksheet was given that included specific instructions. Then, the trainees developed their first program and investigated the relation between power of motor and speed of the car robot constructed in the previous session. The factors which influence the final speed of the car robot were discussed in plenary. Then they were asked to investigate left and right turns with both ‘move’ and ‘motor’ blocks and finally they developed their own blocks for left turn of 90^o and right turn of 90^o. Each group uploaded the blocks developed through this activity at the private documents’ area of the group in the e-class. Finally the groups were asked to make their robot move on a square path (final programs were uploaded). Their programs included blocks like ‘move’, ‘motor’, ‘record’, ‘loop’, whilst they also defined their own blocks.

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During the second section, the trainees worked in groups with the project 'The cat, the mouse and the master' introducing basic programming structures and statements of the Lego Mindstorms Education NXT programming environment. Initially a mock up with black spots was put on the ground simulating the area where the cat is moving - each black spot corresponds to a mouse! -. The groups should adapt their robotic construction in order to make it work on the mock up as a cat running after a mouse. Three activities that gradually introduce trainees to different programming concepts of varying difficulty and complexity were proposed. Each activity sets a specific challenge-problem to the trainees:

– at first they should make the cat run after the mouse and stop when it reaches a black area (the mouse!) using a light sensor, the loop block, and developing their own blocks,
– then the cat's behaviour should be 'extended' to be able to stop for a while and make a sound when the master touches her. To this end, the cat robot should be extended to include a touch sensor. Trainees should also extend the program using condition blocks, and blocks like Display, Sound, Wait For,
– finally they should use variables in order to make the cat move on a spiral path.

On each activity appropriate worksheets containing instructions and information about specific blocks of the Lego Mindstorms Education NXT programming environment, were provided, aiming to enable groups work autonomously.

In the discussion followed, many different ideas were proposed about the behaviour of the cat on the mock up, leading to alternative programming solutions.

Finally, in the third section, the data logging functionality was introduced. The particular activity that trainees worked with was about collecting time and distance data from a moving robot and developing graphical representations of the corresponding data that give information about the motion of the robot.

Focusing on a methodology for designing robotics-enhanced activities. This session focused on pedagogical issues arising when designing robotics-enhanced projects for students. This session organised in four sections. Trainees initially reflect on the methodology used in TERECoP for developing robotics-enhanced projects for students. Then they have a real experience working with a real project designed based on this methodology, they discuss their experience and conclude to evaluation criteria for well-designed robotics-enhanced projects. Finally they make their own proposal using the methodology to design a project outline.

Theoretical framework for designing robotics-enhanced projects. A theoretical introduction about project-based learning was made by a trainer. Then the methodology for developing robotics-enhanced projects for students proposed by TERECoP was presented. The particular methodology consists of five stages [5]: engagement, exploration, investigation, creation and evaluation. The particular stages were introduced through a real, fully developed project 'The Bus Route'.

Trainees, working in groups as 'teachers', study how the project 'The Bus Route' is structured in stages and they analyze each stage of the project according to the type of activities involved. Each group undertakes a particular stage, study the corresponding material like the project description and the available worksheets, and comments on the teaching strategies, the role of the teacher, and the students' tasks

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involved. Then the groups present their ideas and opinions and in collaboration with the trainers result in a synthesis. The final product of this work is uploaded in e-class.
Working with a real project. Trainees work in real conditions as 'students' with the investigation stage of 'The Bus Route' project. The scenario of this project was presented and analyzed in smaller problems/questions. Each group investigated a problem/question and suggested a solution. All solutions were presented and discussed in plenary and uploaded in e-class. Advantages of organizing cooperative activities were also discussed.
Evaluation for well-designed projects. In groups and then in plenary trainees discuss and decide on criteria for evaluating robotics-enhanced projects for students within the constructivist approach. This work resulted in a rubric including the main criteria discussed and the level of performance expected for several levels of quality.
Designing a new project. Trainees work in groups to propose an idea for a project suitable for their students. To support this process, several electronic resources (sites on the Internet) with innovative ideas about robotic constructions had been published at the discussion forum of e-class from trainers and trainees during the previous week. Finally, the groups give an abstract description of the project they intend to develop and submit it to the public forum at the e-class.

Trainees' projects presentation and evaluation. Between this and the previous session, a period of three weeks has intervened. Through this time the groups had one kit at their disposal in order to develop a new project based on the proposed methodology. So, during the final session of the training course, trainees present their own projects and receive feedback from the class. The work of each group had already been uploaded on the e-class. In particular, each group presents their project (the construction, functionalities, and suggested teaching – learning activities). Then they receive feedback from a particular group of trainees (compulsory), the rest groups (voluntary), and the trainers. The evaluation process is based on the criteria agreed in the previous session.

Finally, trainees complete an evaluation questionnaire about the course (methodology, organisation, content, e-class, learning experience and integration of robotics in the school reality) and they participate in a semi-structured interview.

3 The e- workspace

In order to enhance class communication during and beyond the face to face meetings, we created an e-workspace that we maintained through the course. To this end, we used the open source e-class platform of the Network Operation Center (NOC) of the University of Athens (http://eclass.gunet.gr). The trainers created a 'virtual class' or e-class in order (a) to *provide* trainees with *resources* (course content, worksheets, presentations) and *support* such as timely information about the course content & scheduling, useful resources & links, on-time support through the public areas of 'announcements' and 'forums', (b) to *promote a sense of community* among the members of the class (trainers and trainees) providing opportunities for

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communication/collaboration and resource sharing during and beyond the face to face meetings.

The e-class was organized to support communication and collaboration at two levels: at *class* and *group* level. To this end, we used *public areas* for all the members of the class with different rights for trainers and trainees like the ‘Announcements’ area that permits trainees to make announcements to the class, the ‘Documents’ area that allow the trainers to upload content whilst trainees only to download the available files, the ‘Agenda’ area that allow the trainers to describe the course structure with time and session information, the ‘Links’ area where the trainers may suggest interesting Internet sites to the trainees, the ‘Forums’ area (see Fig. 2) for discussing topics where trainers and trainees are allowed to create discussion topics and submit messages. Moreover, each group was provided with a *private area* for uploading files,. We also arranged *private areas for each group* where trainees could upload their products when working with activities (such as programs or texts, the group diary at the end of each session, the material of their own project), discuss topics, and exchange e-mails. This area was also accessible by trainers. In several cases, the trainees could share their group products if these were copied in the public area.

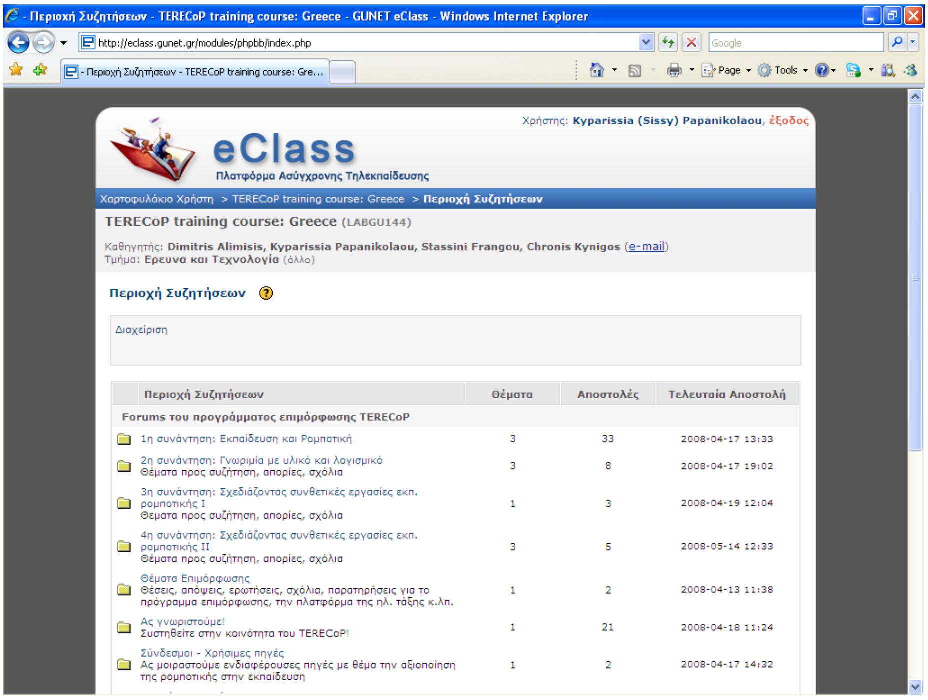

Fig. 2. A screenshot of the e-class of the training course. The public forum area is depicted organised in different topics.

During the course we used the *public areas as tools* for *administration purposes*, for example for providing the course content and worksheets before each session and timely information about the course organization or each individual session, as well as the *public and private areas* for *teaching purposes promoting reflection and social interaction.* For example, we used the public forum to organize a 'helpdesk' where everyone could submit a problem or provide a solution, to stimulate trainees introduce themselves and share their expectations, to make trainees express themselves in specific discussion topics, share and reflect on their peers' ideas, experiences, and perspectives - e.g. trainees at the end of each session submit a comment on their learning experience of the day or suggest interesting and useful links on the Internet whenever they locate it-.

4 Trainees' Projects

During the course, trainees had to design their own projects based on the proposed methodology. Six of the seven groups of trainees developed and submitted interesting projects. All the groups worked with the Lego Mindstorms kit and programmed the robotic construction with the Lego Mindstorms Education NXT version 1.0. Below we provide brief presentations of the six projects.

Project 1: selector of recycled garbage. This group consisted of two mathematicians (a woman and a man) and two computer scientists (2 women). The man had strong experience on Lego Mindstorms, whilst the three women were beginners. In this project, students work in groups in a laboratory equipped with computers and some Lego Mindstorms kits. Students are invited to construct a simulation of a selector of recycled garbage able to identify the colour of different objects - normally garbage bags come in special colours (see Fig.3). The selector decides if the object is to be recycled or not based on its colour, and accordingly puts the object in the appropriate bin. The robot is equipped with two belts and a light (or colour) sensor. The sensor checks the colour of the objects and activates one of the two belts accordingly. Worksheets for school students were also produced by the trainees.

Fig. 3. Selector of recycled garbage

Project 2: autonomous irrigation system for water management. This group consisted of a mechanical engineer and a computer scientist (2 men), both having a basic knowledge level on Lego Mindstorms. Through this project students are invited to design and construct an autonomous

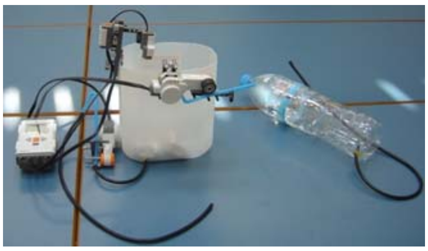

Fig. 4. Autonomous irrigation system for water management

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irrigation system for water management. The basic functions of this system are: (a) fill up a tank and control of the water level, (b) control of watering from the tank during the night.

The main challenges set by this project concern (a) avoiding water loss while filling up a tank, i.e. the tank must not be overflowed, and (b) automatic provision of water from the tank when it is getting dark and the climate conditions favour watering. The characteristics of the system can be changed or enriched by students' ideas. Lego Mindstorms NXT kit, a plastic tank and watering pipes are used for the construction of the system (see Fig.4). The project is organized in 5 stages following the proposed project–based learning methodology. It aims, in addition to other objectives, to sensitise students about the rational management of water resources.

Project 3: Organizing seats in a theatre. This group consisted of a computer scientist (woman) and two physicians (men), all beginners. In this project, students are invited to construct and program a robot able to follow a predefined route in order to count the free seats in a theatre or cinema or ground, and inform the man in charge about the free seats of the whole place or a specific section (see Fig.5). Extending the project, this robotic construction might also check tickets and place the audience in the corresponding places.

Fig. 5. Organizing seats in a theatre

Project 4: Easy parking. This group consisted of a computer scientist (man) and an architect (woman), both having basic knowledge on Lego Mindstorms. In this project students are invited to construct a car-robot able to perform 'easy parking' on a mock up having several obstacles (see Fig.6). In particular, the robot should be able to identify blank spaces, avoid obstacles by turning left or right, stop, and park at free car parking places.

Fig. 6. Easy parking

Project 5: A moving car. This is an introductory project on robotics developed for primary education. In this project, pupils are gradually supported to cultivate basic construction and programming skills. Initially, pupils should construct a car robot and make it move forward,

Fig. 7. The catapult

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backward and turn left or right. Then a challenge is set e.g. to move the car through a specific route and then move it freely in any path. This project can be expanded to a game with many challenges!

Project 6: The catapult. This group consisted of a mechanical engineer and two computer scientists, having basic knowledge on Lego Mindstorms. The project was designed for students of 15 and 16 years old. Students are invited to construct a robotic arm with one motor by following simple instructions (see Fig.7). Then they should program it to throw small balls in a basket (projectiles). In order to make it work effectively, students should conduct experiments with the parameters involved like the length of the robotic arm, the motor power, the projection angle, the horizontal distance etc. Experimental data are collected and represented in graphs using the appropriate software. Detailed examination of these graphs help students investigate relationships among the parameters involved. Finally students may continue playing a basketball game!

5 Evaluation and Discussion

In the training course implemented in Greece, a balanced whole of collaborative, learning- and teaching- focused approaches was adopted. The course evaluation was based on the trainees' products through the course and mainly on the projects they developed, the questionnaires filled by the trainees and the interviews organised. Preliminary results prove the potential of the training approach.

Trainees' projects were presented and discussed in the final session of the course. The trainees' projects followed the 5-stage methodology for designing robotics-enhanced projects that had been worked out during the training course. The description of the projects and the relevant materials (worksheets etc.) produced by the trainees indicate that the trainees efficiently adopted the proposed methodology. The trainees' projects address authentic problems from real life (projects 'recycling garbage', 'saving water resources', etc.) and engage students in problem solving through exploration and investigation activities that exploit sufficiently the potential of the educational robotics.

The trainees' answers and comments to the questionnaires and during the interviews, provided some evidence about the potential of the training course focusing on the training methodology, the content provided, the e-class, the learning experiences and the integration of robotics in the school reality.

Training methodology. Trainees recognised their active participation in all the sessions of the course and their creative involvement even in the theoretical parts introducing constructivist and constructionist principles and the methodology for designing robotics-enhanced projects. Several trainees emphasised that the educator's axiom 'teachers teach as they are taught, not as they are told to teach' was really respected in the course. They admitted that they had a real experience of constructivism ("It was for me a lesson of knowledge construction", "Constructivism was present all the time in the course", "This course was substantially different from the courses I have attended in the past").

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Some comments focused on the synthesis of the groups: trainees doubt about the efficiency of the personal relations criterion for group formation purposes. Especially the group of the primary school teachers noted that “if a teacher of Informatics participated in our group, s/he would have helped us a lot…”. Other trainees emphasised that the cooperation of teachers coming from different disciplines (maths, science, informatics etc.) is necessary for the successful implementation of the projects in school settings given that the projects are normally interdisciplinary.

The communication and cooperation between trainees and trainers was appreciated by the trainees as very supportive and helpful (“we achieved a common language…”). However, they suggest that the duration of the course should be extended and the development of their own project –or most of it- should take place during the course.

Concerning the *educational content* they very much liked the activity-orientation. 75% of the trainees characterised it as very useful and the rest as useful. They also liked that they had a real case of a project (‘The Bus Route’) to analyse the different stages of the methodology. They suggested that more examples and activities for homework would be also useful.

Concerning the *e-workspace* most of the trainees evaluate the central role of the e-class during the face-to-face meetings and beyond them in enhancing social interaction and promoting a positive sense of community. They found the use of the web-based class as an interesting and useful experience that they will exploit in the future as teachers or trainers. They acknowledge the timely provision of information, course content, and support when necessary. They also acknowledge its contribution to an economic distribution of content, resources, and trainees’ products, as well as to knowledge and ideas sharing.

They mentioned that the discussion forum was mainly used for posting messages and not for real discussions since most discussions took place through the face to face communication. However, they expressed their reservations over using an e-class in real conditions as participation and administration are quite time consuming tasks.

Learning experiences and the integration of robotics in the school reality. Trainees acknowledged the potential of educational robotics as a teaching tool but also as a subject in different disciplines such as technology, informatics, and engineering.

A critical issue for integrating robotics-enhanced projects in the schools that was discussed, was how an interdisciplinary project may fit in the current school curriculum and schedule. Interesting ideas were proposed for integrating educational robotics in schools such as working interdisciplinary projects or research programs running out of the school schedule involving students from different levels e.g. engineers from vocational education working with high school students. Trainees seem also to worry about the management of big classes during the implementation of robotics-enhanced activities in school settings (“It will be difficult for one teacher to manage a school class of 30 students…”) and the cost of the necessary equipment.

Finally, trainees highly appreciated the opportunity to create their own project (“a serious gap would have been created, if I had not worked on a new project within my group”). They recognised that at the end of the course, they feel capable to implement the robotics technology in their school class (“I understood how to exploit these new ideas and technologies in my school class”).

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