Integrating Robotics in Science and Technology Teacher Training Curriculum

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Abstract: This paper presents a constructivist methodological approach for integrating robotics in science and technology teacher training curriculum. Two interventions are reported involving two distinct target groups: technology future teachers and experienced in-service physics teachers. They resulted in the development of robotics projects in school classes in corresponding disciplines. Finally, lessons learnt from these experiences are discussed.

Keywords: educational robotics, teacher training, curriculum

1. In the after TERECoP era: integrating robotics in school education

Over the last few years, robotics in education has emerged as an interdisciplinary, project-based learning activity drawing mostly on Maths, Science and Technology and offering major new benefits to education at all levels [1], [2]. The use of robotics in education is aimed to enable students to control the behavior of a tangible model by means of a virtual environment resulting in a learning situation that will actively involve learners in experimentations, research and in authentic problem solving.

However, so far robotics has not been admitted to the official school curriculum and relevant activities are developed mostly due to individual efforts of enthusiastic teachers or actions that take place beyond the formal curriculum mainly in after school classes.

During 2006-09 the European educational project TERECoP (www.terecop.eu) worked to develop a methodology for training teachers and for introducing robotics in school both as learning object and more importantly as learning tool [1]. The TERECoP method was inspired from constructivism educational philosophy [3] and was mostly based on project-based learning. In the after TERECoP era we have worked to implement the ideas of the project in collaboration with teachers and schools in formal and informal educational settings [1], [3]. Our efforts are focused on teacher training and on supporting them to implement robotic activities in school classrooms.

This work presents two relevant indicative actions from two different contexts: training future teachers of technology and further training experienced in-service physics teachers. Indicative examples from these actions and

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corresponding ones from school classrooms are reported. Finally, lessons learned from these experiences are discussed.

2. Methodology

Our methodology views robotic technologies not as mere tools, but rather as potential vehicles of new ways of thinking about teaching, learning and education at large. We appreciate the importance of learners' existing knowledge, conceptions and culture, as well as of their interests and varied learning styles. Our approach encourages learners to participate actively in the learning process. Through robotics learners build something on their own, preferably a tangible object, that they can both touch and find meaningful. In robotics learners are invited to work on experiments or problem-solving with selective use of available resources, according to their own interests, search and learning strategies. They seek solutions to real world problems, based on a technological framework meant to engage students' curiosity and initiate motivation [4].

The robotics industry so far mainly aims at humans using pre-programmed pre-fabricated robots. The ways in which the robots are made and programmed is a black box for their users. It is a paradigm compatible with the traditional educational paradigm of the teacher or the curriculum book revealing and explaining ready-made, ratified and thus unquestioned information [5]. Very differently from this approach, our methodology suggests the transition from "traditional" black-box technologies to the design of transparent (white-box) digital artifacts where users can construct and deconstruct objects and have a deep structural access to the artifacts themselves. The white-box metaphor for construction and programming might generate a lot of creative thinking and involvement in learners [6].

When students can have control of specific robots in a rich learning environment embedding the construction of robots and programs to control them the emphasis might move on interesting learning activities in the frame of specific learning areas such as science and technology.

The design of robotic construction activities is associated with the fulfillment of a project aimed at solving a problem. In such a learning environment, learning is driven by the problem to be solved. To engage students in activities requiring to design and manufacture real objects, ie robotic structures that make sense for themselves and those around them [4], should devise activities that will encourage students to construct but also to encourage them and give them appropriate support in order to experiment and explore ideas that govern construction.

Activities may take the form of research posing problems that are authentic, multidimensional and can have more than one solution. It is particularly important that the problems are proposed to be open and allow students to work with their own unique style and the way they wish. The work will actively involve students in learning opportunities by giving them control and ownership of their learning, encouraging creative problem solving and combining interdisciplinary concepts from different knowledge areas (science, mathematics, technology, etc.). The learning activities are as open as possible so that students have opportunities to participate in the final configuration of them and ultimately provide opportunities for reflection and collaboration within the team.

The role of students

When preparing a work with programmable robotic constructions students first through free dialogue in their group and after that in the plenary session of the class discuss the research problem and devise an action plan to solve it. Then, they work in groups to implement the plan devised taking into account the feedback that they have already got from the educator. Students experiment with simple programmable mechanical devices (eg a car-robot, motors, gears, pulleys, shafts, sensors, etc.) and associated software. Students may redefine the research plan after the experience gained during this work. Students are asked to synthesize their findings and reach conclusions and solutions to the problem under investigation. The final products of the groups are presented in the class, discussed and evaluated. Finally students are asked to address their work critically, to express their views and to record their experiences in the form of a diary.

The role of the teacher

The teacher in such a constructivist theoretical framework [2] like that described above does not work as a teacher - authority that transfers ready knowledge to students but rather acts as an organizer, coordinator and facilitator of learning for students. S/he organizes the learning environment, raises the question / problem to be solved by students, offers hardware and software necessary for their work, discreetly helps where and when necessary, allows students to work with creativity, imagination and independence and finally organize the evaluation of the activity in collaboration with students.

3. Integrating robotics in teacher education curricula

3.1 Robotics in training future teachers of technical secondary education

In the framework of the one-year training programs held for future teachers of secondary technical education at the School of Pedagogical and Technological Education (Patras, Greece), starting from the academic year 2010-11, a robotics module has been introduced normally in the course of educational technology.
The robotic program includes:
A theoretical part including presentation and discussion of the theoretical background and the educational potential of robotics, suggestions on the potential use of robotics in school courses of students' specialization, a presentation of the package LegoMindstorms, of the programming environment Lego Mindstorms Education

software and of the Lego Digital Designer, a software simulating robotic construction (used to facilitate students in their first constructions).

A laboratory part: students participate in a series of practical activities taking place in the Educational Technology Laboratory (the time length is determined each time from the available teaching time). An illustrative scenario follows:

a. Students are divided into groups of 3-4. Each group is allocated a Lego Mindstorms NXT kit and is invited to discuss the construction, to design with pencil and paper the construction, and to build a vehicle with Lego Mindstorms. Each team designates a representative to present to the plenary of the class their construction. An excerpt from the worksheet given to the students is quoted below:

Use your Lego Mindstorms kit to build a car.
The car should have ...
- A frame (chassis) like this in picture
- 4 wheels
- An engine that will actuate the two front wheels
- The "smart brick» Lego Mindstorms should give instructions to the motor to rotate
Talk to your team and draw roughly the car here as you think you can build ...
You can use the model available from Lego Digital Designer for your construction if you wish…
Make now the car and prepare to present it in class…

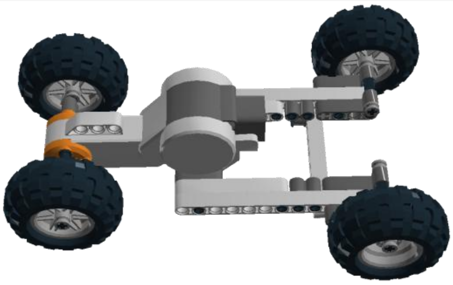

Fig. 1. Focus on simplicity: a simple car realized by student-teachers

b. Introduction to programming robotic constructions using the Lego Mindstorms Education NXT

The students practice with the basics of Lego Education NXT software starting with the Block “move”, the controller to load programs from the PC to the robot, use and operation of the touch, light, sound, and distance sensors, to control the block “wait” and more. Students are free to experimenting in using the software with the car they have already constructed. The trainer helps discretely the students when necessary without limiting their inventiveness and self motivation Each group appoints a representative to show the class the results of their work. The trainer comments and makes suggestions where appropriate.

c. the lab activities continue with specific problems involving control of motors and sensors, such as:

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Take your car to move forward with the throttle (Power) at 70 for 1 seconds (second) and brakes, then about 2 seconds, then about 3 seconds. What do you conclude from this experiment?
How can we make the car-robot, as it moves, understand the obstacles that touch, stop and turn back?
d. Design and implementation of a team project by the students:
The trainer invites students to design and realise their own scenario. Students work in groups to implement their ideas by programming the robot car and are invited to describe in their own words the solutions provided. Each team designates a representative to present their work to the class. The trainer comments and make recommendations where necessary.
Upon completion of this training, students are encouraged to implement robotics activities in classroom on subjects of their choice. For this purpose we use the context of teaching work experience and our partnership with local schools which we can facilitate our students for their internship. One such example is shown below.

A case study: Teaching programming concepts in school through robotics
This case study was realised by two of our student-teachers specialized in informatics. Robotic vehicles built with Lego Mindstorms kits were used in a lower secondary education class of informatics (April 2011, Patras, Greece) to support the learning of making decisions and loop control programming concepts. Robots (simple cars with four wheels, one motor and one ultrasonic sensor) were appropriately programmed by the pupils to perform simple actions, which involved the use of making decisions and loop behaviors in computer programs.

The student-teachers explained using concrete examples just the basic building blocks of a program (move, wait, conditional wait, loop, switch etc.) along with the steps necessary to build a program and download it to the robot. After that, pupils were invited to imagine a behaviour for their robot involving decision making and/or repetition and then describe it using paper and pencil before programming it to their robots in the second part of the activity. At the end of the activity, the groups were asked to present the behaviours they thought of and demonstrate them with their robots in front of the whole class. Most groups managed to program the actions after some trial and error attempts. The student-teachers acted as experienced advisors, encouraging the students towards the solutions but not doing the work for them. Finally, they evaluated their whole teaching intervention based on the analysis of pupils' work as it had been saved on the computers of the laboratory and on the analysis of pupils' diaries [7].

After the end of the project, the student-teachers' experiences were recorded through a written report [8] and a non-structured oral interview. As the student-teachers reported, the feedback collected from the classroom verified their initial assumption that a robotics activity would be appealing to the students and could help in bringing abstract concepts closer to the pupils. They appreciated the opportunity they had to explore the difficulties encountered by the pupils working out the new programming concepts, to understand how students preferred to work and finally to gain insights on how future educational activities should be planned and designed. The robotic activity enabled student-teachers to see the results of their actions in the school class reality getting immediate feedback from pupils, which as they reported increased their self confidence in using robotics in school [8].

Evaluating this action, we can first identify the obvious similarities between the methodology proposed in the training course and that applied by the student-teachers in the school class. We can claim that student- teachers successfully implemented the robotics-based methodology they had been taught on a topic of their own choice and specialization in a real classroom setting. Second, this connection between training course and school class proved useful for them because they were provided valuable feedback from pupils' work which convinced them that the use of robotics in the proposed methodology is realistic and feasible and finally strengthened their self confidence for future use of robotics in school.

3.2 integrating robotics in further training for in-service physics teachers

In the framework of further training courses for in-service physics teachers held in the University of Athens (September-December 2011), we introduced robotics in the curriculum of the course for 10 teaching hours for a group of 6 trainees; all of them had long in-service experience and high qualifications. The main aim of the robotic curriculum was to explore together with the trainees ways to use robotics as tool for learning focusing in the phenomenon of motion and the basic kinematics concepts: time, distance, speed, motion at constant speed, motion at accelerated speed.

After the necessary familiarization with the Lego Mindstorms NXT kit (5 from 6 trainees were novice in robotics), where we followed the same methodology described earlier, we focused on laboratory activities in teaching the phenomenon of motion and the relevant kinematics concepts.

Trainees worked in two groups of three exploring the following questions and designing suitable laboratory activities using a robotic car. An ultrasonic sensor had been attached to the car to provide data on the position of the car.

1st question: What is the relationship between the time of the robot motion which you click on the software and the real time motion of the robot?

The trainees chose different times through the software to move the robot and checked the relationship of those data with real time motion data of the robot. They filled in a table of values and a subsequent graphical representation.

2nd question: What is the relationship between the number of rotations of the robotic motor you select in the software and the distance traveled by the robot?

The trainees measured the radius R of the wheel of the robot and calculated the distance traveled by the wheel in one full rotation. Then they checked experimentally whether the theoretical values coincided with the actual distance traveled in each case by the robot. They made again a table of values and a subsequent graphical representation graphing the linear relation between number of rotations declared to the software and real distance traveled by the robot.

3rd question: What is the relationship between power of the motor you select in the software and the speed of the robot?

The trainees chose different values of motor power using the software, measured the actual distance traveled by the robot at a certain length of time for each value of power. They filled in again a table of values and a subsequent graphical representation resulting in a linear relation between the two variables.

After these basic explorations they were invited to design an experimental activity for their students useful to study the rectilinear motion at constant speed. At this point the function data logging of the software Lego Mindstorms was introduced.

After several trials with the robot moving on the floor, the trainees devised the programming solution given in fig. 2 resulting in the linear graph (fig. 3).

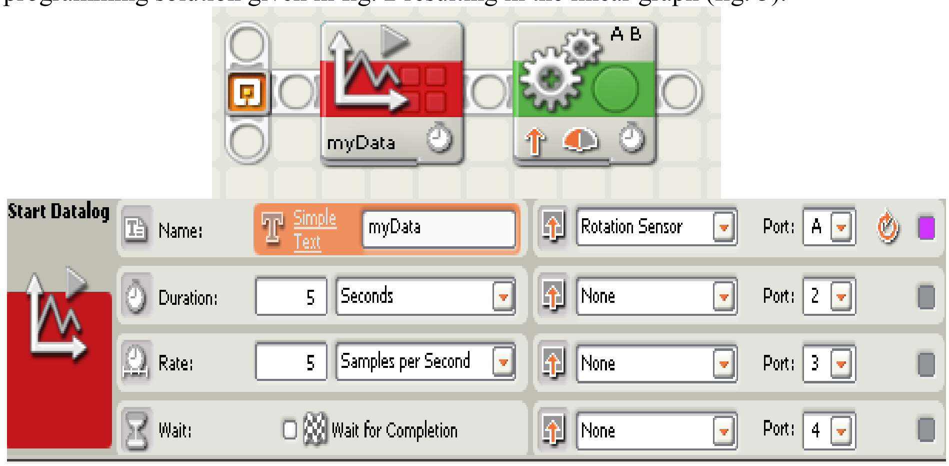

Fig. 2. Trainees' program for motion at constant speed

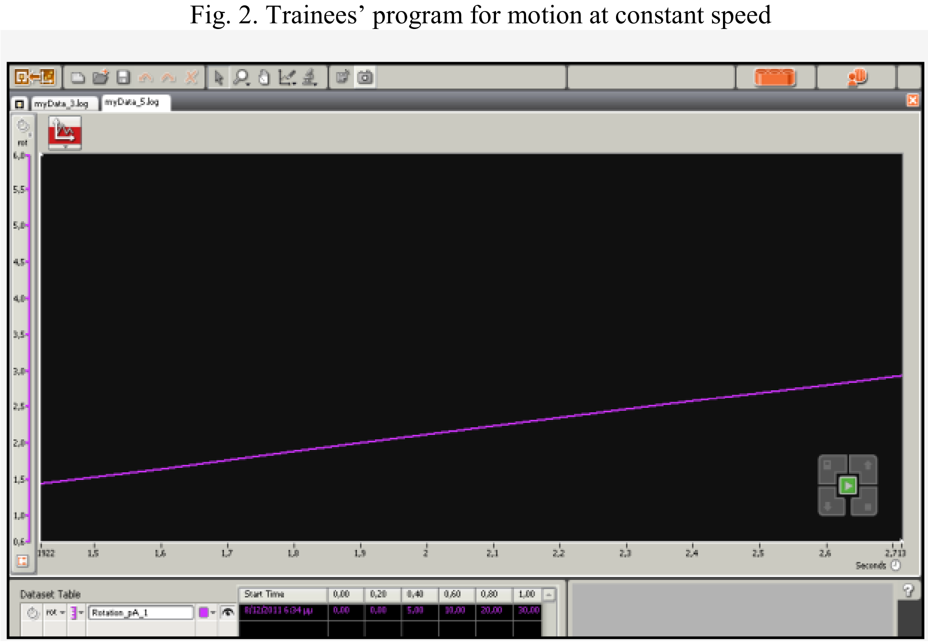

Fig. 3. Constant speed motion: Position-time graph (screenshot from data logging)

The next challenge was to make the robot move in straight accelerated motion at constant acceleration. For this purpose, the programming technique of repetition and arithmetic operators were introduced. The result from trainees' programming work appears in fig. 4 and the graph position – time in fig. 5

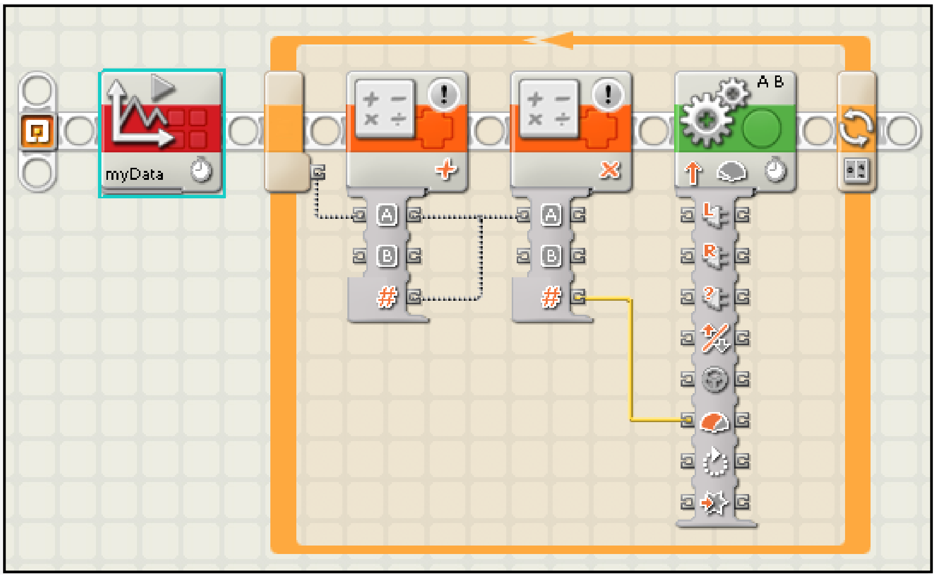

Fig. 4. Trainees' program for accelerated motion

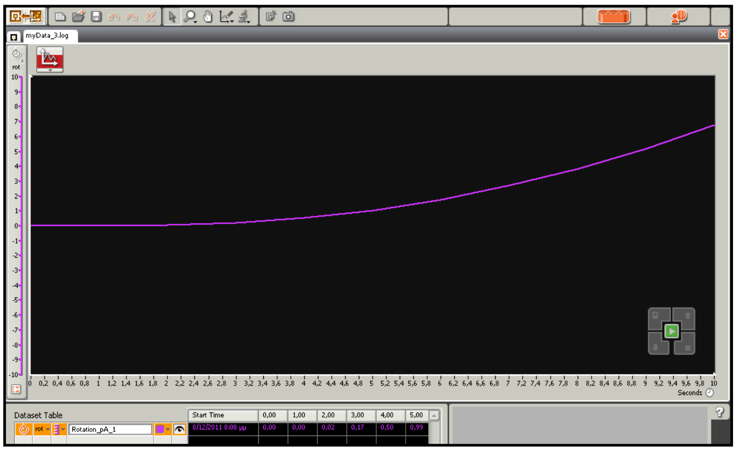

Fig. 5. Accelerated motion: position-time graph (screenshot from data logging)

In the discussion that followed for the evaluation of this experience, we concurred with our experienced trainees that the methodology followed had provided a study of motion concepts through active participation of the learners, had built step by step the a deep understanding of the concepts, had triggered curiosity and encouraged further study and research. The use of robots had allowed repeated and controlled by the user experiments. Programming motions and devising algorithms that result in linear

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motion with constant velocity or constant acceleration can help in understanding the movements themselves. Finally, the execution of the programmed movements of the robot could allow students to see their thinking, as expressed in the algorithm, to come alive with the robot moving on the floor and understand any mistakes or successes.

4. Conclusions and future plans

This work identified two pathways for integration of robotics in teacher training programs: first, in the initial education courses for technology teachers and second, in the usually shorter further training programs for in-service teachers of science. A constructivism-inspired methodology was presented common to both cases, but specified according to the specialisation, needs, interests and existing educational experience of learners.

In the first case of future teachers, linking training with teaching interventions by the learners themselves in classrooms where they were asked to implement the ideas that had been taught during their training, has proved very useful, as demonstrated by the case study coming from the reported classroom experience. The successful implementation in classrooms offers a criterion of success of the training program itself.

In the second case of the experienced teachers a specific methodology was selected that focused on utilizing the existing rich experience of trainees and on sharing with them the effort to explore new ways to use robotics in learning science.

Teachers achieved by themselves, after an initial familiarization with the necessary tools, to create experimental activities which they considered useful for their students to understand the relevant scientific ideas by following the constructivist methodology proposed in the training course. The ideas formulated in this program are already being tested in classrooms by volunteering teachers, and the results are awaited with interest.

The field of science and technology is a privileged one for the development of robotics. In collaboration with enthusiastic young and experienced teachers new activities in this field and classroom interventions are planned or are underway, which are expected to provide valuable new ideas and data on the integration of robotics in the curriculum of science and technology in the near future.

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