Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 174 (2015) 3838 – 3846
Procedia
Social and Behavioral Sciences

INTE 2014

Teaching robotics at the primary school: an innovative approach

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Abstract

Many researchers and teachers agree that the inclusion of Science, Technology, Engineering, and Math in early education provides a strong motivation and a great improvement in learning speed. Most curricula in primary schools include a number of concepts that cover science and math, but less effort is applied in teaching problem solving, computer science, technology and robotics. The use of robotic systems and the introduction of Robotics as a curricula subject can bring the possibility of transmit to children the basics of technology and to give them other kind of human and organizational values. This work present a new program introduced in an Italian primary school thanks to the collaboration with National Instrument and Università Politecnica delle Marche. The subject of Robotics becomes part of the Primary school curricula for all the five years of formation. The program has allowed the teachers training and a complete way through which children have demonstrated great learning abilities, not only in mere technology but also in collaboration and teamwork.

Peer-review under responsibility of the Sakarya University

Keywords: Robotics, primary schools, innovative program.

1. Introduction

Many researchers have been investigating the use of robots to support education. Studies have shown that robots can help students develop problem-solving abilities and learn computer programming, mathematics, and science. The educational approach based mainly on developing logic and creativity in new generations since the first stage of

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Peer-review under responsibility of the Sakarya University
doi:10.1016/j.sbspro.2015.01.1122

education is very promising. To these aims, the use of robotic systems is becoming fundamental if applied since the earlier stage of education. In primary schools, robot programming is fun and therefore represent an excellent tool for both introducing to ICT and helping the development of children's logical and linguistic abilities of children. Robotic teaching experiences have been carried out in Italian schools since 2000-2001, when the first project was proposed. It was called "Building a robot" and its description can be found in [Merlo, 2010]. Moreover, learning robots programming also becomes an opportunity for primary school pupils for developing their linguistic and logical skills, always focusing on pedagogical rather than technological issues. This paper presents an innovative program developed in order to teach robotic basics at the primary school as a curricula subject. The same instruments are used as a multidisciplinary validation and motivation for other subjects (Italian, Mathematics, Science, etc…). Education in Italy is compulsory from 6 to 16 years of age and is divided into five stages: kindergarten (scuola dell'infanzia), primary school (scuola primaria), lower secondary school (scuola secondaria di primo grado or scuola media), upper secondary school (scuola secondaria di secondo grado or scuola superiore) and university (università). The Scuola primaria (primary school), also known as "scuola elementare", is commonly preceded by three years of non-compulsory nursery school (or kindergarten, "asilo"). Scuola elementare lasts five years. Until middle school, the educational curriculum is the same for all pupils: although one can attend a private or state-funded school, the studied subjects are the same. The principal subject are Italian, English, Mathematics, Natural Sciences, History, Geography, Social Studies, Physical Education and Visual and Musical arts.

Until 2004, pupils had to pass an exam to access Scuola secondaria di primo grado (Middle school), during which they had to demonstrate their abilities in composing a short Italian essay, passing a Math test and an oral test regarding all the other subjects. The exam has been abolished, only private primary schools legally recognized maintains this kind of test. In order to introduce Robotics as subject during the Prinary school five years, a special program has been introduced. The global five-years schedule is divided into two main blocks: during the first two years pupils are introduced to logics and mechanical feel with remotely controlled independent machine (using Lego WeDo system); in the last three years childrens are asked to design, build and program their own independent robots, using Lego NXT system.

The LEGO Education WeDo is an easy-to-use robotics platform that introduces young students to hands-on learning through LEGO bricks and the easiest form of graphical programming software that National Instruments has to offer. It is a fun and simple way to get younger students exposed to basic engineering concepts at an early age. The use of LEGO Education WeDo provides a hands-on learning experience that actively engages children's creative thinking, teamwork, and problem-solving skills. LEGO Education WeDo is a hands-on platform that primary school students can use to build simple robotics applications driven by a personal computer with a simplified version of LabVIEW. By combining the intuitive and interactive interface of LEGO Education WeDo software with the physical experience of building models out of LEGO bricks, students can bridge the physical and virtual worlds to provide the ultimate hands-on, minds-on learning experience ([LabVIEW Graphical System Design]). The system has being applied in other countries, proposing their use in primary schools and studying the possible benefits for children education. In [Mayerovà, 2012], for example, the author analyzes the first-contact situation in which 3rd grade pupils in primary school encounter LEGO WeDo for the first time. In [Romero, 2012], a pilot study of robotics in primary schools is described, together with motivation of choosing The LEGO WeDo for children activities: the low learning curve of the programming language (visual programming rather than code writing), and the educational content provided with it.

Recent years have seen the development of cooperation between National Instruments, Università Politecnica delle Marche and primary schools to improve the use of new technologies since the first grade of the school. One of them is Primary School Istituto Comprensivo Largo Cocconi.

Both the scientific and educational communities recognize the role of ICT company investment in improving science and engineering education, engaging students with technology, and equipping educators with resources to help them teach fundamental engineering concepts in a fun, hands-on way. Specifically, the National Instruments and Lego provide interactive, real world learning experiences; low-cost and free training opportunities; a strong global mentorship program; technology and funding.

Initiatives such as K12Lab.com for primary and secondary school teachers and the NI courseware portal for university professors feature effective content that educators can use directly or adapt to their learning environments [http://k12lab.com]. The K12Lab is a website where teachers can browse and share lesson plans, find inspiration from what others are accomplishing with technology, and get tools and support to help their students connect theory to reality faster. K12Lab users gained access and contributed to a growing library of 86 lesson plans for subject areas such as physics, robotics, and computer science.. The Austin Children's Museum (ACM) creates innovative learning experiences for children that equip and inspire them to be the next generation of creative problem solvers. The ACM program, TechReach, provides students from low-income families with opportunities to gain hands-on science, technology, engineering, and math skills. Working with LEGO MINDSTORMS NXT kits, participants learn the basics of designing, building, and programming robots. The TechReach program addresses a three-fold problem for economically disadvantaged children in Austin: shortage of access to technology, the need to build 21st century skills, and the lack of interest and awareness in a science-related future [9, 10]. Another interesting experience could be found in the Lana Stone, a technology instructor, with the Govalle Primary school team partecipation on the FIRST LEGO League. National Instruments recently chose to partner with "The Boys & Girls Club", a non-profit organization dedicated to enabling all young people to reach their full potential as productive, caring, and responsible citizens. At the clubs, youth are provided a safe place to learn and grow ongoing relationships with caring adult professionals, life-enhancing programs and character development experiences, as well as hope and opportunity. In the project the LEGO Education WeDo has been used. The kids who attended the workshop ranged in age from 6 to 15 years old. It was clear that they had not been exposed to this type of technology before which made the volunteer's experience particularly rewarding. Many of them had interacted with LEGOs but were extremely excited to make a LEGO robot that moved. One child was surprise at a LEGO alligator that bit his finger through the use of a motion sensor is: "It is always motivating to see the eyes of a child light up when they learn something new." It was also rewarding to watch the proud, glowing faces of the parents who were dragged into the computer lab by their kids who wanted to show off the robots that they had built and programmed [austintexas].

Following what already done in the past form a lot of institutions and the experiences in pedagogical, technological and teaching aspects the here presented project arises from the collaboration among three principal groups of researchers from Università Politecnica delle Marche (UNIVPM), of teachers from Istituto Comprensivo Largo Cocconi and the National Instruments Company for the hardware involved in this work.

The paper will presents the different aspects of the project and the preliminary results. The presentation is organized as follows: Section II describes the objectives and the expected results of the project; Section III explains the instruments and times used to realize this project, while Section IV illustrates the preliminary results, and the conclusions and future developments are illustrated in Section V.

2. Objective and expected results

The first and main aim of this project concerns the introduction of Robotics at the Primary school as a normal subject in the curricula besides being proposed as a lateral extra curricula activity to be performed out of official school hours. The projects wants the children to increase their capabilities, teaching them to program a machine and to consider robotics as a normal method of work rather than an exceptional way of operating. With robotics, the students can have a different opportunity for developing their logical ability and their creativity, features at the base of reasoning and critical thought. The first experimental work done in the last five years has covered a complete Primary school cycle; it has been performed with the priority of introducing the subject ROBOTICS as a curriculum component, improving the usual Gantt of the regular Ministry plans with a new teaching theme involved in its Didactic years, weekly Programming and the regular learning evaluation methods.

The presented scholastic program has been divided within the five years of Primary school and the new study program for each Class is proposed in the following.

The main objectives of the project are distributed as follows:

1. Class I

- Learning the roboethics concepts with the introduction of the Asimov's literature and the three robotics laws;
- Gaining knowledge of the single mechanical elements through simplified programs of ordering and planning: learning the differences among shapes, materials, colors and functionalities of the elements presented on the market;
- Planning a model using LEGO system through a simplified program;
- Understanding the model verification and validation concepts in the work environment.

2. Class II-III

- Acquiring the ability to attribute coherent purpose to a constructed robot;
- Introducing to the concept of ROBOT as a machine that must complete a specific task;
- Studying sensors and actuators through the comparison with human apparatuses;
- Introducing the software programming for the LEGO WeDo system.
- Realizing a simple robot able to interact with the environment.

3. Class IV-V

- Acquiring the ability of attributing coherent purpose to a complex constructed robot.
- Acquiring the ability of building a robot in accordance with specific and relative complex purposes.
- Planning a robot for a specific scope of research, that is able to live in a defined environment.
- Introducing software for robot analysis.
- Realizing a technical manual for the final operator in order to explain how to design and realize a robot.

During the quinquennial of the educational training the main objectives are accomplished by mean of different activities.

The activities are scheduled in didactic units, different for each school year and class. Each didactic unit consists in specifics aims and skills developed in activities, increasing and pursuing children competences.

The first activity is aimed firstly at involving the children to collect the changes in the surrounding environment about the technologies development. Secondly, the same activity is focused on the relevance of practical activities, to increase curiosity, fantasy, and logic in the children. The evaluation of the accomplished knowledge is be checked asking children to realize a document filled with images about different robot duties and aims useful for human being.

The second activity concerns of the approach to the Robotics laws, in particular guiding them to analyze the necessity of the three laws and their connection to society laws. The purposes are to educate children to social values and to have respect for others; moreover, it becomes important to underline the necessity of establishing rules that save and increase the well-being of all people. Another aim is to learn technological progress as a positive aspect in life, and to increase collaboration with other subjects giving own contribution to the group. Practically, teachers help children to learn and to apply the three robotics laws working with pictures.

The third activity is aimed at planning and building a robot made of structured and not structured materials, using WeDo for the first two years, NXT for the third and the fourth classes and custom hardware with COTS and LabVIEW for the last year). The objective is to increase logic in the activity of materials discrimination and classification, coherently increase creativity in order to handle different materials, and try to make objects with the use of acquired skills. The children are asked to pass two final tests. The first, where the children have to correctly classify different robot pieces and a second where the children have to put in order the different parts to make a robot. Other evaluation activities are carried out in groups; each group have to assemble pieces and to build a robot.

The fourth activity concerns the training on how to program with visual development tools (mainly the WeDo and the NXT with an introduction to LabVIEW). The final aim is to give some basics about programming, using a

visual framework, which is, therefore, quite simple and intuitive; at the same time, they start discovering the new functionalities made available by a computer. They learn how programming a robot and its specific functions that change according to the abilities the robot itself has to show. Then it is important to stimulate children to think about personalizing the robot program. The skills developed with this work are the comprehension and the execution of deliveries and instructions for understanding and communicating own experiences in clear way, being able to use computer and graphic programs and lastly to attribute purpose to an object. This work is aimed at understanding the single blocks during the elaboration of the program realized. The teacher supports the children when they have difficulties during the software production, or they can be tutored by classmates.

The fifth activity aims at building and programming a robot, according to specific aims: examination of the robot skills, classification of building pieces, robot software production and check of robot work. This project is aimed at getting pupils confident with materials manipulation, stimulating their curiosity, dealing with new challenges. Moreover, it is important to transmit the feeling of group spirit and working together towards a common goal. This activity helps children to understand how to solve a problem or mistakes in their work by finding alternatives, and at the end to understand the necessity of respecting the three laws of robotics in building and programming robots. The final test of this activity wants to verify how the children create the Robot according to the assignment. They are required to produce a text where the process is explained. The above composition can be done individually or collectively.

The last activity involves the elaboration of fantasy texts in which the protagonists are the constructed robots. The aims are: collaborating with classmates, bringing positive contributions to the group, learning to accept other people ideas, to respect differences, understanding the necessity of rules that safeguard the well-being of everybody and finally increasing creativity and fantasy through the production of a coherent text. The enhanced skills are instead to understand and to execute deliveries and instructions, communicating own experiences in clear way, interacting in a conversation through questions and narrating direct experiences, observing and confronting.

These scholastic activities will emphasize the importance of the prefixed objectives for children and it is very important stimulating logic and ability of analysis. The continuous exercise encourages them to stimulate the curiosity in specific cognitive instruments, to reinforce the abilities to attention and concentration and to observe experiments with the use of the scientific method.

3. Instruments and times

The time established for these activities is placed within the “hours for the optional disciplines” established by Ministry in the regular timetable weekly magazine of the curriculum activities. The plan include didactic trips, beginning from second-third class of the primary school, inherent to the programmed activities, in science museums or research institutes, where the pupils will be involved in more specific workshops about mechatronics and robotics.

The hardware and software involved in this project for the children training include five kits of LEGO WeDo® (Fig. 1) for the first and second classes, five Kits LEGO MINDSTORMS® NXT (Fig. 2) in the other classes.

Università Politecnica delle Marche, LEGO Education and National Instruments together provide the framework for learning how to systematically and creatively solve problems. This means understanding key science, technology, engineering and math concepts. The UNIVPM, LEGO Education and NI platform helps teachers with the power of robotics, useful to create learning opportunities for students for developing the skills like creation, problem solving and contribution to a global society.

Fig. 1. Lego WeDo® kit

Fig. 2. LEGO MINDSTORMS® NXT kit

National Instruments and LEGO, sharing a vision of inspiring creativity and innovation in children, have already partnered to develop the next generation of LEGO MINDSTORMS® - programmable robots that are smarter, stronger, and more intuitive. Starting from LabVIEW, graphical system design software used by scientists and engineers, a more user friendly desktop software has been developed which turns any LEGO MINDSTORMS® Education set into a full-feature science and engineering learning station, preparing students for high grade school, university courses and engineering careers where LabVIEW is already used.

LabVIEW for LEGO MINDSTORMS® is the most advanced software environment for programming the NXT. LEGO MINDSTORMS products take maximum advantage of NI's world-class software for their latest hardware innovations, delivering LabVIEW software to applications spanning from kindergarten to rocket science. The WeDo Robotics Construction Set is a set of pieces and mechanical parts that can be used to build robots. The WeDo is designed to teach simpler concepts to slightly younger kids, and it uses many recognizable Lego pieces. The WeDo Software allows programming the robots, controlling its actions, sounds and responses. All the programming is drag-and-drop; just line up programming blocks to tell the robot what to do. The educational training is focused to a specific knowledge of the robotic subject and the base language for programming its functions. The teachers also will gain these specific competences, so they will be modernized on the topic of computer science, industrial and theoretical robotics. Educational developing meetings with the teachers about the construction of activities for the pupils in the class will be scheduled.

4. Preliminary results

Preliminary results are based on activities described in the second Section, carried out in a given period of time. The proposed criteria have been able to teach new concepts to children, to attribute coherent purpose to a constructed robot, and to teach the roboethics with the introduction of the Asimov's three robotics laws. Selected groups of professional operators will have also invited to attend and to take part to intermediate tests and experiments.

The first experimental Robotics subject has been taught in the Istituto Comprensivo Largo Cocconi in Rome – Italy. The primary school teacher Mariantonietta Valzano and the University professor David Scaradozzi developed the experimental project after their observation about primary pupils. They focused the project on increasing and pursuing logical and creativity, important educational skills in modern school. They succeeded in starting the project four years ago in the mentioned school.

During the project, a responsible role has been assigned to one teacher of the Primary school (Mariantonietta Valzano). Her main role has been the definition of educational objective, the localization of the learning strategies, and the organization of formative activities with the pupils involved. The second person involved in the project is Cinzia Vergine as adviser of didactic activities, with the role of controlling the participation to these learning strategies. She has been responsible of formative activities with the pupils. The third person involved has been David Scaradozzi, as the technical designer supervisor. He has studied and developed the technical instruments and he head the technical training for teachers and pupils.

The team project during this term has collaborated whit Scuola di Robotica di Genova and Mondo Digitale di Roma, attending diffent kind of situations and skills.

Actually, at the middle of the fifth year, the preliminary results concerns:

- Definition of educational objectives;
- Creation of strategies to learn;
- Planning of formative activities with the pupils in classes;
- Planning of the times to release software, hardware and technical training for the teachers.
- Verification and validation of the didactic program
- Technical and computer science training to learn the bases of robotics.

Fig. 3. Children programming with Lego Mindstorm

Fig. 4. Children constructing a simple robot with Lego components

Fig. 5. Children during their trip at University

Improvements registered by teachers are very relevent and have demonstrated the grate value of using robotic system in eahc aspect of teaching. Pupils have been always courious, receiping the single aspects of the training, from the pure robotic construction and programming to the importance of working together, in group, of achieving new skills, and facing new problems. Fig. 3 and 4 show some students directly involved during the practical activities, in particoular the visual programming and the mechanical construction of the robots.

The last figure shows students during the planned trip to Università Politecnica delle Marche in May 2014, where they were intriduced to the world of administration and learning at University, and they participated to a workshop about the LabVIEW professional framework. Teachers have scheduled to complete training LabView Professional the next school year, giving to students the basis of professional robot programming.

Teachers have stated positive differences in educational results if compared with other classes not involved in the project.

4. Conclusion

In September, the fourth year of the pilot project "ROBOTICS IN SCHOOL" has been started in the Institute Comprensivo Largo Cocconi in cooperation with engineers from Università Politecnica delle Marche and National Instruments, who believed in the validity of the training project providing the tools used in these years.

In October 2012 the project received “la medaglia del Presidente della Repubblica”, an Italian award recognizing the most innovative project of the year during the Global Junior Challenge competition event.

The project allows children to get awareness of the robotic science and to develop a good knowledge of the technology they are using. Lessons are aligned with the students’ curriculum. This project showed a great upgrade in the children education, in particular to develop general skills necessary in their life. The curriculum involves the entire engineer design process from ideation, to construction and implementation. This innovative way of transmitting skills revealed to be useful for all types of academic pursuits. This program helped students to develop the skills that will be necessary to be successful in the 21th century.

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