Teaching with Minirobots: The Local Educational Laboratory on Robotics

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Abstract. In this paper, we are going to present and discuss a few activities related to the application of minirobots in school education. The activities have been carried out in the framework of the Local Educational Laboratory on Robotics (LELR), which has been developed by Scuola Superiore Sant'Anna (SSSA) in collaboration with local Municipalities (i.e. Valdera Union) and a network of primary and secondary schools (i.e. Costellazione Network) in the Valdera area of Tuscany, Italy. The LELR is part of SSSA efforts to actively participate in the scientific and technological education of young generations, starting from school age. The laboratory is based on the deployment of robotics, in its several manifestations. in teaching activities. Drawing on preliminary activities and experiences, the paper will report on and discuss a few projects about teaching with minirobots in primary and secondary schools education, pointing out the relevance of promoting an interdisciplinary approach to minirobots educational activities – namely not limited to scientific and technological subjects – as well as developing a critical attitude towards scientific and technological progress in students.

1 Introduction

Autonomous minirobots have brought robotics to a wider audience. In the last decades, schools started to use them to teach fundamental subjects such as maths, physics, logic, programming language, mechanics, electronics, etc, exploiting the

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ludic and fascinating features of robotics and so their ability to motivate students to learn. The philosophy behind educational robotics refers mainly to Seymour Papert theories [1], which described the advantages of using simple construction kits and programming tools for educational purposes. According to Papert's perspective, children, by using robotic kits could became active participants in their learning and creators of their own technological artefacts, not just users of devices that others had made for them [2]. This theory inspired the development of the Logo programming language, an easy to use programming language, which students could use to animate their technological inventions. An interesting application of Logo involved a "floor Teacher Education on Robotics-enhanced Costructivist Pedagogical Methods turtle," a simple mechanical robot connected to a computer by a log cord. Floor turtles made drawings on paper commanded by Logo programs, by using pens mounted in their bodies. In the late 1970's, with the introduction of personal computers faster and more accurate turtles were proposed for didactic laboratorial activities; these novel instruments offered more opportunities for children to investigate and solve complex mathematical problems. Successively, in the 1980's, the first microcomputers entered schools. They allowed children to explore their own ideas by building specific problems to evaluate them. Moreover, in the mid-1980's, it was introduced the LEGO/Logo technology, the first true robotic construction kit ever made available, which consisted of the combination of the popular LEGO construction kit with the Logo programming language [3] [4]. By using the LEGO kit, children could build machines by using the traditional LEGO building bricks and newer pieces like gears, motors, and sensors as well. By using the Logo programming language, children were then allowed to construct behaviours for their artefacts [5].

Although the LEGO/Logo technology was highly efficient it had some drawbacks related, for example, to the nuisance caused by the wires connecting the robot to the computer, which made it difficult for children to create autonomous and mobile robots. Some of those drawbacks were overcame by a new product: the Programmable LEGO Bricks, which appeared in late 1980's. This novel solution could run without wires providing in this way autonomous function to children's mechanical constructions [6]. The last release of LEGO kit consisted in the LEGO Mindstorms kits (http://www.legoeducation.com). They were based on research and ideas from the Lifelong Kindergarten group at the MIT Media Lab [1], [5], and were soon diffused world-wide in both elementary and secondary schools as well as in higher education programs. Lego Mindstorms kits, with respect to the previous releases, included servo-motors, new sensors and the NXT-G iconic programming software but can also be supported by a variety of other programming languages (such as NXC, NBC, leJOS NXJ, and RobotC). Moreover, combined with Crickets, which was another robotic technology, developed in parallel with Lego Mindstorms, they gave children novel and funny instruments to learn important math, science, and engineering ideas; as an example, they allowed the creation of musical sculptures, interactive jewelry, dancing creatures (http://www.picocricket.com/). The Cricket functionality was successively reinforced with the introduction of novel elements ("Display Cricket", "MIDI Cricket", "Science Cricket", "Cricket Bus system") ,which provided true analog-to-digital converters on the sensor inputs, so allowing the use of a greater variety of sensor devices [6]. The main goal of Cricket was to allow children to design their own scientific instruments for investigations which they personally found meaningful; in this way they could gain a deeper appreciation and understanding of many scientific concepts [2].

Other interesting explorations were also allowed by Cricket [5], by adding computation and other functionalities to traditional children's toys (Bitballs Project); some of those functionalities were provided by built-in microprocessor and LED or built-in electronics and infrared communication [5].

In the following we briefly describe some of the most important results of the most significant experiences of educational robotics, made around the world.

- Kärnä-Lin et al. (2006), through qualitative action research, identified various advantages, introduced by the use of educational robotics, into learning in the field of special education. They demonstrated as the robotic technologies make it possible for students to practice and learn many necessary skills, such as collaboration, cognitive skills, self-confidence, perception, and spatial understanding [6].
- Dias et al. (2005), described the positive outcomes of three higher education initiatives in Sri Lanka, Ghana, and the USA that focused on implementing robotic technologies for developing communities; they examined the intersections of robotic technologies with education and sustainable development [7].
- Pekarova et al. (2008), commented the results of the integration of Robotics in Early Childhood Education; according to their observations, developing attractive activities resulted an effective practice for learning with digital technologies at preschool age [8].
- Rossi et al. (2007), observed that robotic programmable bricks enabled students to make possible new types of science experiments for children. All these activities meet well the goals set such as an increase of the quality and impact of education in the primary schools [9].

Summarizing almost each of the activities performed till now, world-wide, on educational robotics differed very much from each other, in their target audience (e.g., primary schools, secondary schools, universities), their pedagogical goals, their organizational background; the diversity of the approaches among different studies prevented, to some extent, a coordinated approach. Moreover many of the described activities lacked of a previous identification and incorporation in the school curricula of an appropriate teaching method.

In this paper we present a further way to employ minirobots in educational research activities and applications, taking inspiration from the following key sentence in the call for papers of the AMiRE 2011 Symposia: 'autonomous minirobots are a microcosm of advanced embedded systems technology that permeates our technological culture'. Based on the fact that technological culture is starting to permeate also educational activities, we argue that educational activities with minirobots could benefit from promoting interdisciplinary activities and a critical attitude on science and technology in students. As a matter of fact, microrobots are an accessible example of what, in bigger scales and in much more complex ways, exists and will exist in our future societies. However, too often, educational activities with minirobots are centered around teaching strictly scientific and technological subjcts. In other words, they are devoid of any connection with other disciplines, such as literature, philosophy, art, or ethics, which, in our opinion, should be complementary and essential for a complete technological and scientific education. In addition, proposing interdisciplinary activities on robotics can have positive effects on creativity and innovation, can be fundamental for the development of problem solving abilities, besides eliciting a critical, as opposed to a passive, attitude towards technology.

The aims of the LELR is to participate in the education of young generations by providing schools with human and technological resources for carrying out several kinds of activities involving minirobots, based on the conviction that robotics can be a useful tool for teaching and learning in a funny and constructive way. The LELR approach to educational robotics is strongly characterised by:

1) the promotion of interdisciplinary projects: it seeks to exploit not only the technological and scientific potential of robotics, but also its connections with other school subjects;

2) the generation of a critical attitude towards technology: the assumption is that students should not be passive receivers or users of technology, but they should be taught what is inside the technology and how it works in order to generate in them a more responsible use as well as insights on the possible risks that technology may raise.

The paper, therefore, will report on a few experiences in educational activities with minirobots in school education which were carried out or planned in the framework of the LELR.

The paper is organised as follow: in the next sub-section we will introduce a few examples of connections between robotics and non strictly scientific nor technological subjects; in section 2 we will briefly describe the LELR's functions and aims; in section 3 will report on two preliminary experiences carried out in the framework of LELR in order to attempt to make a systemic integration of robotics as cross-disciplinary learning instrument in the schools from primary to secondary.

1.1 Robotics and Its Connections with Other School Subjects

Robotics is a subject with multiple educational potentialities and can be used also by involving school subjects other than science and technology, such as biology, mechanics, electronics, computer science, etc.). The following are just examples of possible connections between on the one hand Robotics and on the other Literature, Linguistics, Arts, Philosophy, Sociology and Cultural Studies, respectively.

Literature
Didactic activities involving the teacher of literature could focus on reading and analysing selected literary texts about robots, such as the play R.U.R. (Rossum's Universal Robots), the sci-fi novels by Asimov's or more classical texts such as A.

Huxley's Brave the New World (1932), Mary Shelley's Frankenstein (1818) or Samuel Butler's Erewhom (1872) and then discuss the author's view of scientific and technological progress.

Arts
(History of Art) Didactic activities on arts and robotics may start from the study of various automata built in Europe throughout several centuries, such as the mechanical clocks of the Middle Age, the toys and tricks of the Renaissance, for instance, Leonardo da Vinci's (Leonardo is supposed to have designed a humanoid robot, called "The Knight" in 1495) or the fascinating production of automata of the XVIII century. Since the history of automata is not rooted only in Western countries, but there exist remarkable traditions also in Eastern countries, such as the automata made in the 12^{th} century by Arabian engineer Al Jaziri or the Karakuri ningyo dolls in Japan, it could be possible to design activities aimed at studying the cultural differences in the representation or acceptance of automata in different cultures. The relationship between, on the one hand, the arts and, on the other, robotics or scientific and technological progress can also be studied with reference to paintings, sculptures, theatrical performances and other artforms. Consider, for instance, the faith in technological progress that characterizes the Futurist artists or, on the contrary, the less optimistic view of scientific and technological progress in much of Postmodern artworks.

Popular Culture
There are many movies, comics, TV series and other products of popular culture about robotics, such as music videos, that can serve for didactic activities based on robotics. Many of these products can be used for studying or introducing ethical, legal, social, political and economic implications of robots, such as stereotypes, cultural differences, business interests, legal gaps, social risks, ethical dilemmas, etc. Activities could also be focused on the analysis of the different messages about robotics technologies contained in popular culture. Moreover, many of the stories told in these artform could be used to introduce the topics related to the acceptance of the different (i.e. the monster) and unknown.

Philosophy and Sociology
Didactical activities may have students reflecting on some of the current ethical and societal implications of robotic technologies and systems. They may also be requested to study the relations between philosophical theories and robotics, from the mind-body dichotomy to the current debates on artificial consciousness and intelligence. For instance, to describe a robot by referring to the parts of the human body could be debatable, as it assumes a mechanistic approach to the human being, a way of thinking very popular in the philosophy of XVIII (e.g., Descartes).

Cultural Studies
Robotics, as we have already pointed out, can be used to have students reflecting on their own cultural situatedness and background and to foster a positive relationship among different cultures, for instance, by considering the different approaches to robots in Western and Eastern countries.

2 The Local Educational Laboratory on Robotics

The Valdera area, is one of greatest economic areas of Tuscany, in Italy. The analysis of the main sectors of the local economy shows an area with great potentialities in the field of innovative technologies. This area is characterized by the strong influence of the mechanical division of PIAGGIO, the large company known for the Vespa and for other popular brands of two-wheeled vehicles. In Valdera all the Municipalities are members of the Valdera Union which has the aim to jointly exercise a variety of features and services, in order to exploit the potentially competences of the 15 municipalities associated. In particular, in the branch of Education, the Union supports and encourages the creation of a common training system in collaboration with all the institutions, agencies and associations that are present in the area. For this reason, on November 2010 a pact called "Agreement for the Education of the Community" has been signed in order to define a common educational plan to follow the trajectories of the scientific territorial development. This pact, signed by Unione Valdera; Scuola Superiore Sant'Anna, "Rete Costellazioni"- a local network of schools -, Pont-Tech, and the Municipality of Pisa, will try to encourage the creation of an integrated training system based on Local Educational Laboratories with a shared planning in order to improve education in public schools. The first laboratory that will start will be the one on Robotics that aims to promote and to share the scientific knowledge among the students and among teachers. The choice of Robotics is not accidental in fact the economy of the Valdera area relies heavily on mechatronic skills and technologies.

The Local Educational Laboratory on Robotics (LELR) has started its activities since December 2011. The laboratory involves six pilot schools: 2 high schools, 2 secondary schools, and 2 primary schools. About 10 tutors, among which PhDs students in biorobotics, robotics researchers and technical staff of the BioRobotics Institute of Scuola Superiore Sant'Anna, have made themselves available for collaborating with teachers in designing and developing robotics related activities. Usually a number of 5/6 meetings between SSSA tutors and school teachers are planned in order to design and carry out the activities. Tutors may be invited to collaborate during school time in teaching activities together with teachers. A final public event held at the end of the school year (June 2011) will conclude all the laboratories activities. During the final event, students will have the possibility to present their works to a wide audience outside the school. What is remarkable is that all the activities carried out, which span from 20 to 40 hours, as considered as extra activities both for SSSA people as well as for teachers. No funding or other financial support is expected in the initial phases of the Laboratory. Besides human resources, SSSA is making available to schools its educational robotic platforms, which consists of three robotic dogs AIBOs (Sony), one robotic Dinosaur Pleo (by e-Motion), one humanoid robot I-Droid (by DeAgostini), one humanoid robot Nao (by Aldebaran Robotics) and five robotic kits RoboDesigner (distributed by RoboTech srl). However, many of the activities planned with schools will not be based on commercially available robotic platforms but will consist in the creation of new robotic mechanisms (such as a the realization of a mechanical clock and the application of actuators to a school skeleton) or in the exploitation of the results and materials produced in some research activities carried out in the BioRobotics Institute, such as the European Union funded project Lampetra (http://www.lampetra.org/index.php).

3 Preliminary Experiences with LELR

In the following, we present two projects carried out in the framework of LELR in a primary and secondary schools. Unfortunately the projects has started only recently and it is not possible to provide many details on their implementation and results. However, what characterizes both projects is that robotics is used in connection with other schools subjects.

3.1 Bio-inspired Minirobots for Learning about Nature in Primary Schools

This project, which is called ‘Atelier of the curious minds’ started in January 2011 and was devised by prof. Silvia Coppedè in a primary school of the G. Mariti Institute located in Fauglia (Pisa, Italy), in collaboration with SSSA tutors. It is based on the belief that robotics can be useful for teaching and learning about nature in school activities. The project started with the observation of a living being, i.e. a lamprey. Students were requested to study the animal living environment, its morphological features, the way it moves and behaves, etc. In the second phase, students were asked to observe and study the same features they observed in the real animal, in a robotic version of lamprey, the one realized by SSSA in the framework of the European funded project Lampetra (http://www.lampetra.org/index.php). A small scale version of a lamprey robot was realized based on the previous model developed by SSSA. In this way, students were given the possibility to learn basic concepts, by building or manipulating their model, which can reproduce the main functions of the real animal. A parallelism was established between the observed living being and its robotic double in order to facilitate learning about robotics and nature. The activities were crossed disciplinary in that they involved different subjects, such as linguistics, anthropology, logics, mathematics, creativity and expression, and technological and scientific subjects.

About 15-20 students of different ages, from seven to eleven years old, were involved in this school project. This activities were carried out in a mixed laboratory group where cooperative learning were implemented: children worked on mini robotics platforms divided into small groups of different ages in which personal competence, skills, knowledge were enhanced and amplified.

3.2 Secondary School: From Thinking to Practice with Minirobots

As far as secondary schools are concerned, we report on the project carried out by the school Dante Alighieri, located in Capannoli (Pisa, Italy). The project leaders were Prof. Patrizia Guiggi and Prof. Simona Sacchini, both at their first experience with robotics. The laboratory activities were carried out in the framework of the European project Comenius (http://ec.europa.eu/education/lifelong-learning-programme/doc84_en.htm) which started in 2009. The laboratory involved 15 students aged 12-13. The robotic platform used was the RoboDesigner. The project was characterized by an interdisciplinary approach to robotics, whit a good balance between humanistic and technological/scientific subjects. As a matter of fact, the project was carried out as laboratory activity in collaboration with teachers of other subjects (i.e. mathematics, art, foreign language, technology, literature and even motor activities). The teachers of Italian literature, for instance, proposed to have students read fables/legends (e.g. The Golem), sci-fi short stories and/or novels (i.e. Asimov, Philip Dick, Frederic Brown) or watch excerpts from some popular science-fiction movies, such as Blade Runner, Frankenstein, or Edward scissorshands). In addition, creative writing activities (i.e. inventing and telling tales with robots as characters) were carried out. All these humanistic activities were aimed at eliciting discussions on ethical implications of robotics applications, such as social consequences of human-robot interaction, changes in interpersonal relationships among human beings, acceptance of the different, use of robots instead of modern slaves, etc. Artistic and creative activities were carried out too, in which students were asked to imagine and depict bad or good robots. As to technology and mathematics, Leonardo's machines were studied and taken as models to design and develop simple microrobots and implementing simple programs in C language using a commercially available robotic kit: i.e. the hardware and software of RoboDesigner.

4 Discussion and Conclusions

It is widely acknowledged that teaching with minirobots can be an effective way to have students learn scientific and technical subjects. Futhermore, offering students interdisciplinary activities about minirobots can foster creativity and elicit a critical attitude, especially in relation to the pervasive presence of technology in our societies. We have reported on two activities carried out in a primary and secondary schools in which the activities about minirobots were connected with neithertechnological nor scientific subjects, but on the contrary, they were based on literature, art, and philosophy. Such an interdisciplinary approach required a considerable efforts both from the parts of the teachers as well as that of students: it required a strong flexibility by the teachers and a strong motivation to collaborate by the students. In fact, both students and teachers had to "learn" together to acquire new competences and skills, which are not strictly connected to the traditional school subjects or to their background knowledge.

Moreover, the study of robotics elicited educational methodologies based on laboratory activities and constructivism, in which "doing is thinking". It changed the ways of learning, but also the ways of thinking. In fact, students had to observe an event first, and then to make some hypothesis, to validate his/her own ideas, to design and create. The experimental component was fundamental in almost all activities, students built the robot and thus avoided extreme abstractions and because the robot gave an immediate feedback, that feedback represented an incomparable educational reinforce. As regards to experimental activities, robotics offers teachers a multidisciplinary and highly flexible and effective tool.

In addition, the LELR activities were often planned by dividing students in groups, and this had countenanced the cooperative learning in which personal competence, skills, knowledge were enhanced and amplified.

In the primary school laboratory, the presence of the tutor was aimed at promoting the discussions and the curiosity about the main characteristics of the lamprey. In addition, the tutor designed the school activities taking into account the age of the children and planned the activities in the form of a game. The children showed their fantasy and creativity in the drawings in which they drew the lamprey robot, taking into account not only its aesthetics features, but also the basic components of the robot.

Finally, we would like to make an example of why it is necessary to develop in students a critical attitude. One of the possible risks in using minirobot kits with very young students is related to what can be defined as “the robot as perfect model problem”. In other words, if the robot behaviour is not understood or its real nature is not clearly explained by the teacher, there might be the risk that pupils can see the robot as perfect and themselves as non perfect. This is even more so, if we consider that the idea of perfection is usually associated with the cold qualities of machines, i.e. rationality, perfection, precision, reliability and not with the warm qualities which are usually associated with human beings: humanity, faculty of feeling, faculty for sensation. According to a survey carried out by Arras and Cerqui, ‘humans are better assessed in case they have cold qualities, normally linked to machines’ [10]. The authors points out that ‘from an anthropological point of view this means that the “warm” qualities are no longer those which are considered best in our society’ [10].

In conclusion we believe that educational activities with minirobots should promote and develop in students:

- an interdisciplinary approach and vision of robotics. As a matter of fact, robotics is an multidisciplinary subject. As we have seen previously, it can be easily linked not only to scientific and technical subjects, but also to humanistic subjects, such as literature, history, philosophy, art, etc. Fostering an interdisciplinary approach in educational activities based on robotics is important in order to overcome rigid divisions between subjects, which on its turn may elicit in students a “systemic vision” of reality, critical thinking, curiosity, creativity and improve the management of complexity [11].
- appropriate technological and scientific knowledge as well as “critical instruments” fitted to an increasing complex, ever changing and scientifically and technologically permeated world. This can be achieved by fostering critical reflections on techno-scientific progress and about the not always positive implications on the natural environment and all living beings.

References

[1] Papert, S.: Mindstorms. Children, Computers and Powerful Ideas. Basic books, New York (1980)

[2] Martin, F., Mikhak, B., Resnick, M., Silverman, B., Berg, R.: To Mindstorms and Beyond: Evolution of a Construction Kit for Magical Machines. In: Robots for Kids: Exploring New Technologies for Learning. Morgan Kaufmann Series in Interactive Technologies, pp. 9–33 (2000)

[3] Resnick, M., Ocko, S.: LEGO/Logo: Learning Through and About Design. In: Harel, I., Papert, S. (eds.) Constructionism. Ablex Publishing, Norwood (1991)

[4] Resnick, M.: Behavior Construction Kits. Communications of the ACM 36(7), 64–71 (1993)

[5] Resnick, M.: Technologies for Lifelong Kindergarten. Educational Technology Research & Development 46(4) (1998)

[6] Kärnlä-Lin, E., Pihlainen-Bednarik, K., Sutinen, E., Virnes, M.: Technology in finnish special education: toward inclusion and harmonized school days. Informatics in Education 6(1), 103–114 (2007)

[7] Bernardine Dias, M., Ayorkor Mills-Tettey, G., Mertz, J.: The TechBridge World Initiative: Broadening Perspectives in Computing Technology Education and Research. Robotics Institute School of Computer Science (January 1, 2005)

[8] Pekárová, J.: Using a Programmable Toy at Preschool Age: Why and How? In: Intl. Conf. on Simulation, Modeling and Programming for Autonomous Robots Workshop Proceedings of SIMPAR 2008, Venice, Italy, November 3-4, pp. 112–121 (2008)

[9] Rossi, S.: La Robotica educative nella scuola primaria. Master Degree Thesis, Scienze delle Formazione Primaria, Università degli Studi di Firenze (2007)

[10] Arras, K.O., Cerqui, D.: Do we want to share our lives and bodies with robots? A 2000-people survey Technical Report Nr. 0605-001 Autonomous Systems Lab Swiss Federal Institute of Technology, EPFL (June 2005)

[11] Manifesto on Creativity and Innovation (2009), `http://ec.europa.eu/education/lifelong-learning-policy/doc/year09/manifesto_en.pdf`