

A Piedmont School Net For a K-12 Small Robots Programming Project: Experiences in Primary Schools

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Abstract. PIONEER (PiedmOnt NEt for Educational Robotics) is a School-Net for k-12 "Educational use of robotics" project promoted by school people: teachers and headmasters. Its goal is promoting Papert's constructionism in a cooperation environment for setting up a model of small robots programming experiences in support to standard curricula in previous to university school years. Here we concentrate on primary school activities where educational aspects concerned by using small robots fill a long list: in it, of course, we have mathematics but also education to affectivity, creativity, communication, geography and others. Some experiences from our project are here described in support of our thesis.

Keywords: cross-disciplinary activities, inquiry based teaching technique, pupil centered teaching.

1 Introduction

In July 2007 a group of headmasters of several primary and secondary schools, scattered in Piedmont region, signed an agreement called "Net for Educational use of robotics" aiming at carrying out mutual interest activities for using robots in their schools. For short the project is here called PIONEER (PiedmOnt NEt for Educational Robotics). *More precisely, the project aim was toward experimenting a common path promoting Papert's constructionism in a cooperation project toward a model of small robots programming experiences in support to standard school curricula* [1]. The First Teaching District of Beinasco, with its headmaster prof. Vincenzo Termini, was chosen as leader Institute and S.Siega as pedagogical responsible. The Net also had the cooperation of G. B. Demo from the Dipartimento of Informatics of the University of Turin. All educators associated in the Net had already been involved in ICT projects different in time and in kind of activities. In particular, most of the Net members had been cooperating with G. Marcianó in his *Robotica Laboratory* activities promoted by Piedmont IRRE (Regional Institute for Researches in Education), an Institute that was going to change its functions in

summer 2008. Though also connected with administrative and financial aspects, yet and most importantly, the idea of organizing their schools in a Net originated from teachers field working and was chosen because leading to the conceptual change of gathering together teachers from quite different institutions and creating a shared environment and a common professional guidance with some stability in a situation struck by repeated changes. In their previous activities, educational researchers grouped in the Net already showed the same professional conviction of educating schoolchildren by always connecting the current technology challenges to their common roots as for pedagogy [2] and for didactics [3]. This mingling between tradition and innovation has given rise to a project for an original education methodology where technology is used in order to offer children the pleasure to learn every subject "beyond the pencil and the book" [1]. In minutes of a PIONEER Technical Group meeting we read that the Net aims at *developing, documenting, evaluating and disseminating k-12 educational activities with small robots that must be concrete, feasible and strongly affecting the daily curriculum of students* following Marciano's idea of robotics as a learning environment [4]. Teachers wanted a lasting experience for children could be exposed to the method during several years of their education: plainly a k-12 project was decided where robots should be used with continuity rather than in occasional laboratories hours. Though also some junior and senior secondary schools are involved, most up to now PIONEER experiences concern kindergarten and primary schools, likely because primary school teachers are more prone to cross-disciplinary activities and for innovative methods of teaching standard subjects are considered more successful if applied from the very beginning of children school life.

As we said above, the Net was set up after several members had already been involved in activities connected with small robot programming. To give an idea of these early experiences, in Section 2 S. Siega sketches her activities with a fourth grade class during the school-year 2003-2004 at the Baveno school using one Lego RCX robot (these can be considered early Net experiences because S.Siega currently is the pedagogical responsible in PIONEER). While supporting this experience Marcianó began to conceive the NQCBaby language [5]. Project activities have always concerned several types of robot: during last 2007/2008 year, in Baveno school, *four different types of small robots* have been used programmed with six different languages depending on pupils grades and previous experiences. These numbers prove the growth of experiences as for robot use in that PIONEER school during about five years.

Sections 3 and 4 concern more recent activities. In Section 3 M. Stella De Michele describes her experiences with the Bee-Bot, produced by TTS-group, in a second grade class. Several teachers in PIONEER schools have used the Bee-Bot [6], [7], [8]. For sake of space, here we only address De Michele's activity during last 2007/2008 year that we consider interesting for she was novice to programmable robots. Her experience can be useful to teachers thinking to approach robotics with their first grades pupils and can inspire confidence that good results are achievable when pupils and teachers learn together. Section 4 is a short overview of PIONEER recent activities where students write programs for small robots.

G. Marcianó began the definition of NQCBaby, a Logo-like programming language during his first programming experiences with Siega and her schoolchildren,

in order to have a language children oriented thus easier to use [5], [10]. In Section 5 a short description is given of the current language and of the software tools developed around it for a better use by pupils and teachers.

As for 5-6 years old to 12-13 years old schoolchildren, currently PIONEER counts 100 teachers for about 1000 schoolchildren in 17 different primary schools. The project has received several positive appraisals: Didamatica 2008, the Italian yearly conference on the use of ICT in education, assigned a whole session and a panel discussion to our activities during a full afternoon [9], the pedagogical magazine *Rassegna dell'istruzione* (Education Review) by LeMonnier (Florence) is assigning a special issue to the Net activities that will appear in few months.

Future directions of PIONEER work are sketched in the conclusive Section 6.

2 Early Experiences: from about 2003/2004 to the Net

As we wrote in the Introduction, schoolteacher S. Siega is the current coordinator of the educational network of Piedmont schools involved in the educational use of robotics. Since 2003 she began to program an RCX (kit of Lego Mindstorm) in a fourth grade primary class, after having worked with her pupils using Micromondi software and the Logo language. The pupils criticized both the RCX manual, which proposed poorly varied models, and the robot programming language, that was found to be not enough user-friendly. Pupils also stated that the ROBOT concept must not only apply to an object built using LEGO bricks, but to any programmable object. Thanks to this observation the awareness arose that, using different kits, more children, belonging to different age ranges, could be involved. And this is the big goal that the network of schools today can be proud of having achieved. How?

After the 2003/2004 single-class experiences, G. Marciandò, of the mentioned IRRE Piedmont, proposed the three years project "Educational use of Robotics" for school years 2004-2007. Three schools agreed to his plan: Siega's Istituto Comprensivo of Baveno, the Direzione didattica of Tortona and the Istituto tecnico of Novara. The latter is a secondary school. The project made possible to continue studying and, above all, experimenting with primary school pupils the belief that robotics at school should be regarded as a topic pertaining not as much to the "new technologies", rather to the "new possible teaching methods" in a school-laboratory, i.e. a classroom environment where to "learn how to learn".

On the basis of the experiences carried out those years, often randomly initiated but then consolidated by the more than positive response of the students, scientific measures of possible recognition and validation of educational applications have been proposed and documented. Meanwhile the NQCBaby language was developed as a new instrument specifically designed for an educational use of robots in the school.

After three years, the correct evolution of the IRRE project was the creation of the network of Piedmonts schools to which this paper refers, because of the spreading of good practices produced in nearby schools. The network shares in its work the realization of what S. Papert wrote: "The child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building. ...

Programming a computer means nothing more or less than communicating to it in a language that it and the human user both "understand". And learning languages is one of the things children do best", from the Introduction of [1], [4].

The use of different languages enables students to communicate with different robots. If students like better icons, they may use them rather than a textual language: what is important is the concept of programming. Enter commands to a robot and check if it performs what we want. The immediate feedback allows understanding if we have done a good job OR IF we made an ERROR. In this case we can correct and change the action of the robot immediately!

Our peculiarity as a network of schools consists in the practice of a method of learning by doing. This allows understanding what one is doing rather than learning mostly by heart. "And if today the subject in school learn something is not the content the more important, but the methodology of learning, that can be applied again in the future"¹.

3 First programming activities using the Bee-Bot

The Bee-Bot, produced by the TTS group, is a big bee that can be programmed by pushing buttons on its back for moving forward, backward, turning left, right, starting to move or deleting previous commands. As we wrote, several teachers in PIONEER schools have carried out activities with Bee-Bot. Here we integrate the report that M. Stella De Michele wrote in order to document the activities she, novel to robots, has carried out with her second grade schoolchildren during last 2007/2008 school-year. M. Stella is specialized in teaching humanities but in 2007 promptly agreed to become responsible for the robots experiences in her school and to use the Bee-Bot with her 7 years old pupils in their second grade in order to begin learning with them how to program small robots and how to use them for standard teaching.

"I consider necessary that schools face the technology that surrounds pupils. I used for some years computers with my classes but I was curious of using an object that can move around the way you can teach him either by writing a description of a path or giving the description by pushing buttons as in the Bee-Bot case.

Our story with robots began when my pupils found one Bee-Bot bee on our classroom windowsill. We began trying to understand why this bee, different from those we are used to, was there. We ended to think possible that she got lost because of the pollution and entered in our classroom to rest. The bee was greeted, given a nickname (Maya) and pupils introduced themselves to her. By pushing the buttons on its back children discovered that they could teach the Bee-Bot how to move on the floor (i.e. in a two dimensional space): going straight or turning left or right exactly a **quarter of a cake** (in second grade pupils have not yet dealt with angles and their measures). We discovered the bee could **stroll around** the classroom by pushing more buttons one after the other in a sequence and pushing the \odot button. When pupil asked whether we could make the bee go from one child to another child, i. e. from a starting point to an end point, some child observed that buttons could not be pushed randomly as they had been doing when they wanted the bee go strolling on the floor.

¹ [11], page. 3.

*Making the Bee-Bot go from one child to another requires children to take decisions: first we must decide where to go from where, i.e. design a path connecting the two points. Of course different children suggest different paths. We shall consider some of them and for each path we must decide which buttons to push and how many times, verify if the Bee-Bot moves as we want. If it does not, we have not been good teachers: we taught our bee wrong and we have to change its behavior, i.e. the sequence of buttons pushed. If we want to teach from the beginning the Bee-Bot a correct behavior we have to take some time *planning* what we want the Bee-Bot to do.*

We have to "*be precise*" and discover how far the bee moves each step and so on. Thus we introduced the **concept of measure**: if Maya has moved for a while how can we say how far she went? How do we measure the space covered? First we used several non-conventional tools then we choose the ruler because it gives us a common and (then) a number for the quantity of space covered for each step. To determine how far the bee goes with a given number of pushes one child suggests to sum (one step plus the previous ones) another to multiply (we count all the steps times the space covered by each step). Thus teacher recalls that both are right because we define multiplication using the sum and some child shouts: <Teacher, is this robotics or math? >. Children used their exercise book for drawing the paths they liked better and introducing the Cartesian plane turned out natural at this point, also suggested by some pupil."

We are not proposing here a generalization from one-year experience. The activities here described are an excerpt from our robot activity journal that we will compare and discuss with other PIONEER colleagues that also have used the Bee-Bot. Nevertheless we perceive that, by using a Bee-Bot, first grades pupils

- get a playful approach to robotics and begin to understand what programming a robot is
- are helped in developing their logical thinking and counting skills
- are helped in solving topological problems
- are introduced to problem-solving education
- get used to an *inquiry-based learning (and teaching) technique* even in activities perceived as near to mathematics which is uncommon to experience in first grades [12].

It is important to point out that above activities naturally involved several educational aspects other than those concerning mathematics, more obvious. For example, we considered different reasons why the bee entered our classroom: the pollution story was found acceptable and children wrote the "Bee-Bot Story". Moreover, different forms of pollution, causes, consequences and remedies were discussed: thus some Environment preserving Education has been covered.

Pupils introduced themselves to the bee, gave their welcome holding it on their hands, named it, involved it in their school life showing regard for the new "thing": that is Education to affectivity and to diversity. For every robot experience we had a common discussion time followed by a *self-activity where each child wrote down few lines on what we had done. Children learnt by doing activities with a concrete object and teachers learnt with them.*

4 Primary school programming languages

The current PIONEER draft includes the use of 4 different kinds of robot kits, with different characteristics and functions that allow different kinds of learning: the Bee-Bot, the Scribbler by Parallax, RCX and NXT by Lego. Children can use five different programming languages, according to their skills but also in line with the kit that is being used. Also, thanks to a long-lasting cooperation with B. Demo of the University of Turin it was possible to build a translator for the NQCBaby language with a very simple to use graphic interface, funny and friendly for the children who have immediately accepted it with no problems. This allowed translating from Italian to English (and vice versa) the computer procedures maintaining, and thereby enabling the children to learn, the right approach to commands.

After 4 years of experiments, development, enrichment the schools involved in this network project may claim that the educational use of Robotics, in favorable circumstances, allows kids to learn a lot, attaining powerful skills for their cognitive development. There are institutions, within the network, which, thanks to a more lasting know how, have been able to observe that the students involved in robotics activities for six school years, from the second year of the primary school to the third year of the secondary, are able to build, program and solve problems with robots equipped with sensors and actuators.

Since last year it was possible to experiment both in the kindergarten and in the first years of the primary school the *Bee-Bot*, the bee-shaped robot 2, a programmable machine that involves children in the use of the first computer procedures, as it was said in the previous section. After the Bee-Bot, it is possible to work with the *Scribbler*, the blue turtle (also called "the messy robot") that aims at simulating what the children program in Logo with Microworlds.

In the following years of the primary school, the Lego Mindstorms bricks allow to refine computer programming and technological skills, thanks to the various used languages (iconic and textual) and the implementation of paths with different use of sensors and solutions to problems with more solutions. To conclude, in middle school the "new" robots Lego NXT, complex and refined in its peculiarities, meet different needs of teenagers, never forgetting application of the methodology that the network suggests.

Students educated through Robotics activities in schools of the network, will have a concept of technology not so much as of a black box rather as of a world they can control because they understand it.

5 A textual Programming Language and related software tools

An integrated development environment (IDE) and a compiler of the programming language NQCBaby into the NQC language for the RCX robot are currently available to schools while a compiler of NQCBaby for the NXT robot is being developed by students of the University of Torino, Department of Informatica [14]. Our future aim is to provide a unique textual language children oriented to be used for programming all different robot types used within the project because our pedagogical conception is

toward a platform free method. This unique language is based on the language G. Marciandò presented in several conferences [5]. It is a textual language mother-tongue-based and, according to the Logo philosophy, with primitives coming from children language: thus a children oriented rather than a robot oriented language. Indeed our approach is to make children use easier languages rather than building tools to make easier the existing languages difficult for pupils such as "wood icons" for the iconic programming language proposed in [17]. The PIONEER methodology defines an NQCBaby gradual introduction to schoolchildren with language enrichments from children at beginning-to-write level that use NQCBaby0 to NQCBaby6 level, usually for junior secondary school. NQCBaby0 is the kernel of the language and the textual form of the buttons commands on the Bee-Bot back.

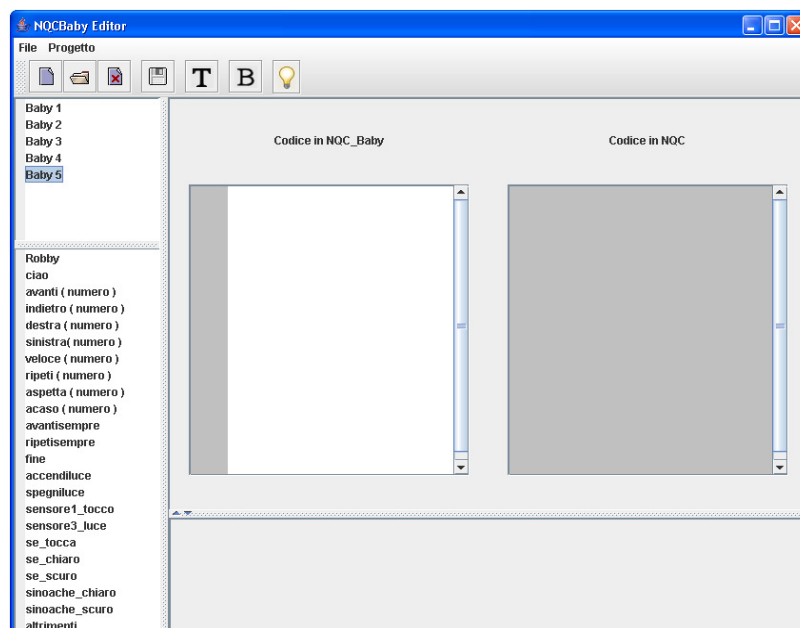


Figure 1. PIONEER IDE window

When writing an NQCBaby program, children use the Integrated Development Environment (IDE) whose windows are shown in Figure 1. The "white board" central to the window is where children write their NQCBaby code. On top left side, we have the tool bar where the button T is used for translating the NQCBaby code. Errors are reported on the bottom with code line. Language levels are written on top of the left column indicated as Baby1, Baby2 and so on. Each next level encapsulates the previous ones and deals with either a different robot needing/allowing new primitives or new hardware components, in general sensors. Ordered introductions of new components, for example sensors, and related primitives for using them in robot-programmed behaviors shall comply the advances of schoolchildren logical and linguistic abilities [5], [10]. So doing robot programming fits the general learning progresses children go through and becomes an original tool for contributing to

strengthening standard linguistic and logical curricula advances. The language grows with children, with their school education and with what they can/want to do with their different robots.

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NQCBaby is not a complete language because our purpose is not making children become good programmers but rather giving them the opportunity to use concrete robots for doing **concrete programming**, i.e. for solving problems by using the basic yet complete structures of algorithmics, as from Jacopini-Böhm theorem [15], [16].

When the RCX robot is used, NQCBaby is translated into NQC, the RCX language proposed by D. Baum [14]. When an NXT robot is used we translate in NXC by means of the compiler under development. For the NXT the last extension of the language provides primitives best fitting the primitives of the NXC language target of the translation. In the following some NQCBaby examples are shown translated in English for sake of comprehension.

The following example is an NQCBaby program describing a robot scrolling around: it might be a program where pupils check primitives of the language with no specific goal. Left column is NQCBaby, right column is NQC language.

Hi Robbi	task main()
speed(3)	{ SetPower(OUT_A+OUT_C, 3);
forward(100)	OnFwd(OUT_A+OUT_C); Wait(100);
speed(7)	SetPower(OUT_A+OUT_C, 7);
backward(100)	OnRev(OUT_A+OUT_C); Wait(100);
repeat(3)	repeat(3)
right(90)	{ OnFwd(OUT_A); OnRev(OUT_C);
left(90)	Wait(90);
end	OnFwd(OUT_C); OnRev(OUT_A);
repeat(2)	Wait(90);
backward(10)	Off(OUT_A+OUT_C);
forward(20)	}
end	repeat(2)
thanks-bye.	{ OnRev(OUT_A+OUT_C); Wait(10);
	OnFwd(OUT_A+OUT_C); Wait(20);
	Off(OUT_A+OUT_C);
	}
	Off(OUT_A+OUT_C);
	}

A second example of NQCBaby shows the function `flip-coin` that in both the NQC and NXC languages corresponds to a call of the function `random`. The NXC version of the program is on the right column. Comparing the NQCBaby and the target code versions of programs here shown, we have examples of what we mean by saying that NQCBaby is a programming language nearer to children than to the robot.

```

Hi Susi
repeat-always
  speed(75)
  forward(500)
  if (flip-coin = heads)
    right(1);
  else // it's cross
    left(1);
  end;
end-repeat;
thanks-bye.

task main()
{ while(true)
  { OnFwd(OUT_AC, 75);
    Wait(500);
    if (Random() >= 0)
      { OnRev(OUT_C, 75); }
    else
      { OnRev(OUT_A, 75); }
    Wait(360);
  }
}

```

6 Conclusions

As we wrote in Section 2, experiences here described began with one teacher and a small numbers of pupils. Without high schools, nowadays the project counts, 100 teachers in 17 different schools for about 1000 schoolchildren from 5-6 years old to 13 years old. Having these already large numbers of pupils doing robot experiences here described for some years now, one of our future activities will concern evaluating competences acquired by these students. Moreover, teachers of the Net will continue the development of the methodology but also to use it as an every day teaching tool in several disciplines, which is one of the peculiar aim of the project. An effort is also toward extending the number of secondary schools involved in order to follow the students that have programmed robots in primary grades as they progress in their school life. The homogeneousness and the common support of the pedagogical method while carrying out the activities, tough the geographical distribution and the different types of schools involved, is another peculiar aspect of our project.

Besides all the cross-disciplinary innovative activities that students will experience with robot programming, other important results specifically concern digital literacy competences. PIONEER pupils learn how to write in a formal language, what an integrated development environment tool is and how to use the one we implemented specifically for this project; they learn what a translator is, its error finding action and use different translators for the different robots. We can definitely say that their digital literacy is to the one of pupils only using any Office suite or similar, as the musical technique of piano players is to the one of stereo players, following the *Pianos Not Stereos* paper by M. Resnick, Bruckman and Martin [18].

In their future, our pupils will know very well how to master the skills acquired at school and competence "we want the ability of management of knowledge and techniques, knowing how the knowledge and integrate them into work, can put its resources by making use of adjustments cognitive and one a series of transactions mental complex"[19].

Next year activities plan also concerns intuitions on inquiry-based teaching techniques that seem possible also in scientific subjects, particularly in mathematics, in primary school. This would be quite a positive change with respect to often currently used teaching techniques that present mathematics as a mechanical exercise

of memory particularly in primary schools but unfortunately also in secondary schools where, as an example, Euclidean geometry problems are disappearing.

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