When a Bee meets a Sunflower

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Abstract. The paper describes a project which involves two first primary classes and was dedicated to a reproduced natural scenario, with two protagonists, a bee (represented by a Bee-bot robot) and sunflowers. Learning motivations and approach, objectives, expected results, details of how the activity was designed and conducted are presented. Some evaluations of the experience and its outcomes complete the presentation and give substance to the proposed approach. The activity originated by a training course dedicated to constructionist educational robotics.

Keywords: Educational robotics, Primary education, Bee-bot, Constructionism, Learning by discovery.

1 Introduction

Technology is currently perceived as a pervasive aspect of everyday life: this can lead parents to expect that the school system introduce ICT very soon. But the introduction of technology at any school level is not a value 'per se' and must not act as a temporary myth or an illusory panacea for any teaching/learning problem [1]. What makes ICT at school valuable is the possibility to use technological advanced tools for promoting joyful interests in STEM and in other disciplines [2][3], to organize a collaborative and project-based learning [4], to make open-minded evaluation of real life experiences [5] reproduction and simulation of the physical reality giving a deeper understanding of our surrounding world together with a clearer awareness of our intimate perceptions (see Tinkerability in [6]).

With respect to other technologies, robotics is proved particularly powerful as a learning tool due to its attractiveness, its multidisciplinary, its easiness to be integrated in broader multimedia and multi-channel learning projects [7]. Recent researches [8] [9] [10] provide proofs of the positive effects of good practices and cues for conducting calibrated, effective and relatively low-cost laboratory experiences at any level using robots. Most research work has been done at secondary and university level, but literature has started to propose good examples and

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researches also at kindergarten and primary school [11] [12] [13]. Even pupils with severe problems can benefit from educational robotics [14] [15].

When introducing robotics in a primary class, special attention must be dedicated to motivate the role of the various actors in the project: teacher(s), robot, pupils, and other recognizable elements of the scenario. The robot can be a sort of protagonist but should not be considered as the only centre of attention during the development of the project. Other elements play relevant importance: the story which acts as the glue for all the developed elements; the realization of accessory artifacts, like other characters of the scene or objects of the story; the importance of discussions within groups and among groups about the aspects related to the story and to the task of the robot. In all this scenario the robot embodies a specific aim: it acts as an operative delegate of a pupil or a group of pupils. After an articulated design the actions for the robot are programmed to achieve established goals which are significant and particularly rewarding in the pupils' perspective [16] [17]. Though the teacher preferably leaves an 'open minded' development of solutions, these goals should be suitably identified in order to make the overall experience reach the desired learning objectives.

This paper describes a laboratory activity done during this present school year in two first classes of a primary school. The story was carefully chosen to allow the teacher to deal with various topics spanning subjects like biology, botany, geometry, earth science, and formalization of actions. The robot used was Bee-bot [18] [19] [20] which has already been proved as an effective platform for this level of school. The project was developed as the experimental part of an intensive training course on Educational Robotics, attended by the primary teacher (one of the authors): after some lectures with a group of teachers at the beginning of the year, the training included the work in class for every teacher. The course was organized following the curriculum developed by the TERECoP project [21]. In section 2 we describe the design of the project and its main goals and expected outcomes; section 3 describes all the preparatory decisions and how the experiment was conducted together with some relevant facts; section 4 is dedicated to the evaluation the obtained outcomes, followed by some final remarks and future development.

2 Project design

2.1 Operating context and cognitive challenges

The activity was designed for pupils of two first class of primary school, with respectively 27 and 21 pupils, with a slight majority of males over females. Up until now, we used, about 11 hours per class during the curricular hours for maths, science and technology. The main teacher received only the partial support of a special-needs teacher (appointed to regularly support one kid with special needs in one class).

In designing and carrying out the activity some specific aspects usually shown by a group of this age was taken into account. In fact, in the 6 years olds you see the overcoming of the childish syncretism (global, undifferentiated perception of reality) and the appearance of analytical ability, hierarchical structuring of the phenomenal

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field, adoption of a reversible perspective, the ability to perform exhaustive explorations, the development of the constancy of magnitude and its measurability. At this age, reversible operational thinking matures, memory expands becoming not only episodic but also schematic, the capacity of representation strengthens, the pupil begins to coordinate two perceptions following in time and to perform first simple classifications and serialization. Moreover there is the slow and complex transition from pre-causality to causality and the ability of distinguishing between a rational and a fantastic explanation arises.

Starting from all the aspects briefly summarized above, we designed the experience to propose a path of development that would have stimulated the described cognitive transition, not giving the robot a secondary role. We were first looking for an argument acting as a general subject, and a motivating excuse, for the experience, easily identified in a usually known flower like the sunflower and an insect which could have a special relationship with it, the bee. This second choice would have simplified the introduction of the robotic component due to the Bee-bot specificities. Apart from the robot, all the other elements used during the experience should have been low-cost and easily obtainable components, with a good degree of repeatability of all the phases.

2.2 Objectives and expected results

Main objectives which have been taken in to account during the design:

- to start stimulating some discussions which should instill the desire for literature and family research;
- to establish a link between the first ideas and abstractions built during the initial phase and the 'robot game', in a constructive way;
- to make the pupils perceive the constrains imposed by the adopted robot and harmonize them with respect to the robot's goals;
- to define a suitable form for coding sequence of actions of the robot and control the transfer of the sequence onto the Bee-bot;
- to convince the pupils (this is not very hard!) that following the trial-and-error procedure is an absolutely acceptable strategy;
- to lead the pupils to perceive and assume direct responsibility towards the other components of the group, and accept team working;
- to emphasize the multidisciplinary aims of the experience;
- to valorize the discover-by-experience approach, a sort of serendipity that can bring a deeper understanding and learning.

This project involves pupils who face scientific aspects probably for the first time. Thus the main expected result was the ability to discover relevant facts from research, direct observation, simulation and discussion. Such an experience was largely based on team work and we expected that the pupils learn how to collaborate for a shared purpose. In the Papertian perspective we expected also that the awareness of the importance of teamwork for problem-solving purposes were made easier by integrating the robotic component in the experience. The depth in the comprehension of all the scientific details encountered will be evaluated all along the experience through observations, discussions and Q&A sessions with the teacher.

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3 Conducting the experiment

The preliminary research, organized on an individual basis as homework with the help of families, was aimed at finding information about the flower, its growth, its behavior, its utility for human and animal nutrition, and on the insect and its many interesting aspects. One specific theme suggested for deepening was the relationship between sunflowers and bees, how a bee moves to reach a flower and how it communicates to other bees the position of an 'interesting' flower.

Fig. 1. The realization phase of the prototype

Fig. 2. The design phase of the prototype

The laboratory part of the experience was conducted with groups of 4 kids each. The first step of this part was to choose materials and, more specifically, for building robotic prototypes taking inspiration from the scientific information previously collected. The idea of constructing these prototypes (i.e. physical models of bees which could in principle be subsequently motorized and rendered autonomous) (Fig. 1), it represents the sort of cognitive link we mentioned above. This construction was preceded by a graphical design (see Engineering design process in [22]) (Fig. 2) through which pupils were free to imagine their prototypes with appearance and potentiality fruit of their knowledge and fantasy. The prototypes, being actually simple puppets, express their potential only ideally: therefore the teacher can easily motivate the introduction of the programmable robot which responds to a need of performing dynamic and 'intelligent' behaviors as the natural completion of the role of the bee in the story.

Also the 'robot game' was anticipated by a paper-and-pencil design. We defined the first task of the robot: there is a sunflower, drawn on the sheet that acts as the plane of movement; the bee, starting from a point near one border, must reach the flower along a path made of segments which have a size multiple of the Bee-bot step and parallel to the borders. The groups were asked to code the sequence of movements using a textual language: its keywords are the Italian translation of the Logo-like base

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commands (forward, backward, right, left and pause). The evaluation of the repetition factor necessary for long straight movements was made easy using a squared paper and considering one square edge as the Bee-bot step (Fig. 3). After having agreed on the apparent correctness of the program on paper, the translation of the code into commands (i.e. robot button pushes) did not offer great difficulty, though the repetition parameter of the moving commands requires a transformation into a suitable sequence of one-step commands. This first task was followed by a couple of more challenging options: to reach first one flower and then another one in a different position; to come back to the starting point after the flower tour and make a small 'dance' to communicate to the other bees the presence and positions of interesting flowers.

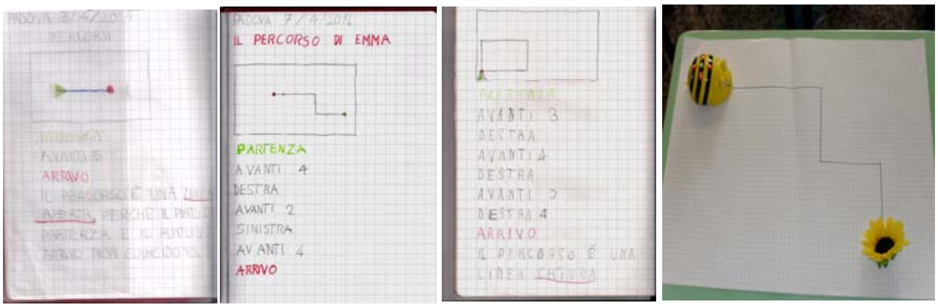

Fig. 3. The programming language and the robot game

To give the project a broader view of the context and to stimulate other competences, the experience was accompanied by an activity related to botanic aspects: some sunflower seeds, initially germinated in a mini-greenhouse, were put into different containers and the groups were asked to classify the different types of seeds, to make observations on the germination and growth using a lens, and to write their comments on their exercise book.

4 Evaluation of the results and conclusions

The experience presented in this paper was initially proposed by the primary teacher as an example of a didactical unit during the training course. Through a successive refinement in the design it became an actual multidisciplinary laboratory activity where learning by doing, project-based learning, open-minded discussions, constructionist approach, inquiry-based learning as opposed to ex-cathedra teaching, were not empty-of-meaning words but precise guidelines for what eventually developed in the classrooms. Observing the steps suggested by the teacher during the experience, you can find a classical refinement cycle through: documentation, design, realization of the prototype, coding, programming the robot, evaluation, where the results of the evaluation can motivate refinements for any of the previous steps. This structure is also related to the phases which were considered the basis of the TERECoP methodology for introducing robotics in the curriculum [23]: engagement, exploration, investigation, creation and evaluation. Moreover, when preparing a

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multidisciplinary experience like the one presented here, we should always emphasize the importance to ask even very young pupils to report whatever they have done or found. Reports showed a correct use of language in describing both natural and technical details. We also observed that the accountability shown by the pupils when applied in a scenario of cooperative learning translates into forms of spontaneous group solidarity, not solicited by the teacher.

Regarding the work with the autonomous robot, its importance and degree of satisfaction is easily accepted by the pupils because the robot is perceived as a natural strengthening and improvement of the realization of the 'static' prototype, and therefore relevant for the personal expectation. The robotic component permitted to more naturally introduce some important geometric concepts (like segment, open broken line, close path, and in perspective perimeter and area of a close figure) together with the identification and perception of regularity of figures and also a first idea of angles, with a better awareness of the learnt abstractions through a constructivist approach.

The adoption of a textual command language was successful and without faults or great difficulties in terms of proper understanding. A language with keywords having unambiguous meanings for pupils better allows open discussions and reasoning, thus it makes the transfer of knowledge among groups and between the teacher and groups easier. It was also useful to promote a trial-and-error approach when, for example, having to move two steps aside on the left, the incorrect sequence of 2 left rotation was rapidly corrected after the robot had showed the error with evidence. Also the effectiveness of teamwork was proven by all the materials of good quality produced by the groups and by the richness of the discussions spontaneously emerging or solicited by the teacher.

About the expected results mentioned in paragraph 2.2, all of them were essentially obtained. The assessment of these results, for this first experience, was done through a more careful evaluation of the usual *in itinere* verification tests and through an observational research [24] supported by check lists and a diary. Tests delivered at the end of the year revealed noticeable improvements with respect to some initial evaluations, (namely, 21% of the total in one subject, 49% in two subjects, 30% in three). Kids was observed in action during the laboratory moments and outside those moments during the entire period of experimentation, taking notice of all the interesting reasoning, behaviors and discussions spontaneously produced. This 'observing on the field' ask the teacher for an attitude of listening and attention oriented to capture all those signals relevant for the evaluation. Documentation is provided in the form of photos and collecting digital materials when possible. The gain reached by integrating the autonomous robot in the experience was positively evaluated in terms of problem solving degree, easiness to rapidly reach correct solutions, depth of the learning process with respect to all the scientific elements introduced in the experiment. We are consequently convinced that robotics makes all these achievements, which are of relevant importance in the first year of a primary level of education, more easily and deeply obtainable.

One specific aspect worth to be mentioned is related to the low threshold/no ceiling principle. No distinction was applied among the pupils in the class: all of them, excellent, 'normal' and with some difficulties were involved in all the phases (design, prototyping, programming) actively participating to the work of their team. Even in

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the case of a kid with some learning difficulties he could experiment situations of 'good engagement': we observed that the other kids in the group related to him by observing his potentials and not his problematic aspects; in particular the activity with the robot did not create any negative discrimination for this kid. The additional special-need teacher, who was present all the time with the class of this kid, was not forced to concentrate her attention to the group of the problematic kid but could help the main teacher in a rather exceptional broader sense.

Finally we observed that the cohesive moments of discussion and reflection produced a general improved ability to listen and an improved capacity to express their own hypotheses and opinions even for pupils who were not used to relate happily with their classmates, ensuring the general participation of all.

Like in other experiences described in the mentioned literature, the educational robot is actually a powerful cultural artifact and, more specifically, the Bee-bot has proven itself adequate for the purposes of the project and for the level of development of the involved pupils, due to its constructive and programming simplicity, whereas most expectations were fulfilled. This first experience will help to design further robotic-oriented projects involving the same classes in the next year(s) with the possibility to experiment improvements such as a differently dressing of the Bee-bot, integrating the activity with the physical robot with a simulation on a PC, adopting more performing robot kits and programming environments, and a more structured evaluation plan, also taking into account the possibility to get a wider feedback depending on the different age of the kids.

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