Using Robots to Learn Functions in Math Class

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Abstract. *In the present paper we present and discuss an activity realized with K-8 level students using robots to learn functions in the mathematics classroom. Research presented in this paper is framed by project DROIDE which is a three years project. We are now in the first one. The aims of DROIDE are:*

- *to create problems in Mathematics Education/Informatics areas to be solved through robots;*
- *to implement problem solving using robotics in three kinds of classrooms: mathematics classes at K-9 and K-12 levels; Informatics in K-12 levels; Artificial Intelligence, Didactics of Mathematics and Didactics of Computer Science/Informatics subjects at high level;*
- *to analyze students activity during problem solving using robots in this different kinds of classes.*

In spite of we are just beginning the research, first data collected show them as promising and we can already point out some implications for mathematics teaching and learning when robots are used as mediators between students and Mathematics.

Introduction

In late years it become widely acceptable that learning is not a merely individual activity, isolated from social, cultural and contextual factors (Lave, 1988; Collins, Brown & Newman, 1989; Cobb, 1994; Confrey, 1995, in Núñez, Edwards and Matos, 1998). Learning occurs in social contexts that influence (and are influenced by) kinds of knowledge and practices that are build (Lave and Wenger, 1991; Wenger, 1998 e Wenger, McDermott e Snyder, 2002).
Thus, we can not neglect the real world where actual students live – a world more and more informatized and consequently more mathematized. What is important to learn in our days is not the same at the time when students' parents were children.
The evolution of technical capacity of computing equipment and network communication possibilities brought new work dimensions and possibilities. But the great majority of classrooms does not reflect this turn that carried new pedagogical challenges (see Fernandes, 2004).

In Portugal, a lot of research, focusing in the use of information and communication technologies, has been driven, either in teachers' education programmes or with pupils of K-5 to K-12 levels. This research has concerned mainly with the use of a certain kind of software (e.g. GSP, Cabri-Géomètre, Modellus, etc.) and calculators (graphic or not) in the classroom.
Informatics teaching is a recent curricular area in Portugal. Thus, there is few research concerning with that problematic.
Either in Mathematics Education or in Informatics teaching and learning area there are still questions that deserve our attention, namely, the use of robots to teach and learn mathematics and Informatics.

The Project and its Aims

DROIDE[ii]: "*Robots as mediators between students and Mathematics and Informatics*" is a three years project and we are now on the first year.
We place three kinds of aims for the project:

- to create problems in Mathematics Education/Informatics areas to be solved through robots;
- to implement problem solving using robotics in three kinds of classrooms: mathematics classes at K-9 and K-12 levels; Informatics in K-12 levels; Artificial Intelligence, Didactics of Mathematics and Didactics of Computer Science/Informatics subjects at high level;
- to analyze students activity during problem solving using robots in this different kinds of classes.

Thus, we established the following research problem: to describe, analyse and understand how students learn mathematics/informatics having robots as mediators between them and mathematics/informatics.
Within a perspective of interpretative nature – in which empirical work constitutes a guide to the search – we posed a set of questions that we would like to answer with this search:

(a) How do students appropriate certain mathematical concepts using robots?
(b) How do they use robots to learn how to develop algorithms?
(c) What is the role of robots in mathematics/informatics learning?
(d) In which way do robots facilitate mathematics/informatics learning?
(e) How can robots help in developing mathematical and Informatics knowledge?

(f) What is the role of robots in developing students' mathematical competency?
(g) How does creating mathematical/informatics problems to be solved through robots influence upon teachers and future teachers' methodologies of work in the classroom?
(h) How does the use of robots in teachers' education programmes develop competencies in teaching Mathematics and Informatics?

This paper relates an activity realized with K-8 students using robots Lego® Mindstroms™ Robotic Invention System™ in a mathematics class to teach functions[iii].

Theoretical Background

The research took into account Situated Learning Theories (Lave & Wenger, 1991, Wenger, 1998, Wenger et al, 2002). The notion of community of practice, such as it is used on theoretical perspectives of Jean Lave and Etienne Wenger, which consider learning as a situated phenomenon, are used to reflect upon emergent learning within students mathematical and computer science/informatics practices.

According to Wenger et al (2002) practice[iv] is constituted by a set of "work plans, ideas, information, styles, stories and documents that are shared by community members" (p.29). Practice is the specific knowledge that the community develops, shares and maintains. Practice tends to evolve as a *collective product* integrated in participants work and organizing knowledge in ways that make it useful for themselves insofar as it reflects their perspectives (Matos, 2005).

Wenger (2002) proposes three dimensions of the relation by which practice is the source of coherence of a community: mutual engagement, joint enterprise and shared repertoire.

Mutual engagement: a sense of "doing things together". Sharing ideas and artefacts with a common commitment to the interactions between members of the community.

Joint enterprise: having some object as an agreed common goal, defined by the participants in the very process of pursuing it, not just a stated agenda but something that creates among participants relations of mutual accountability; that become an integral part of the practice (Matos, Mor, Noss and Santos, 2005).

Shared repertoire: agreed resources for negotiating the meanings. This includes artefacts, styles, tools, stories, actions, discourses, events, concepts.

Methodology

Methodology adopted is organized in three stages according to the aims of the project: 1st – problems creation; 2nd – classroom implementation and data collection; 3rd – data analyses.

First stage – analyses of School Mathematics and Informatics curriculum by researchers, to choose didactical units where robotics can be used. Creation of problems/tasks (to be solved in Mathematics and Informatics classes).

Second stage – Problems/tasks implementation in Mathematics and Informatics classes.

Data collection - Data are being collected recording, on video, the activity of students observed.

Third stage – analyses of students activity at the time when they work (in mathematics/informatics) with robots. Methodology used has an interpretative nature. Data analysis is supported by Situated Learning Theories. The unit of analysis considered was "(...) the activity of persons-acting in setting" (Lave, 1988, p.177).

Using Robots to Learn Functions: One Problem Proposed

In this part we will present a brief description of the context, of general plan of work for the unit of functions, of problem that were solved, and of mathematical activity and mathematics involved on the problem.

Context

Basic School of Caniçal, created in 1996, is situated at the East extreme of Madeira Island, at Caniçal village, whose population is about 5500 residents. Fishing is traditionally the economic base of the village. Building construction is an alternative as well as seasonal emigration whose implications in familiar structure is visible seeing that, grand parents and close parents are who care with young people. That fact is reflected on school performance of students.

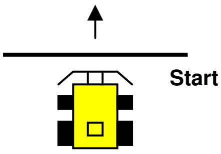
In mathematics class students worked in small groups. The work involved, in a first phase, robots construction and programming to solve simple tasks using Windows® *visual environment programming* that come with robots kits. Subsequently, students used robots to recognise and apply coordinates system in robots programming, understand function concept, represent one function (direct proportionality) using and analytic expression and, to relate intuitively straight line slope with the proportionality constant, in functions such as $x \mapsto kx$.

General plan of work for functions unit

First mathematical unit to be worked was functions. For that didactical unit we prepared four sets of problems. With Problem 1 we pretend that students recognize examples and counterexamples of functions in correspondences presented in such different ways and identify functions as examples of correspondences of daily situations. With Problem 2 we aim that pupils deal with other kinds of graphs, behind straight lines and recognize then as functions as well, if it is the case. With Problem 3 we pretend students to learn direct proportionality, as a function. Direct proportionality definition as a function emerges of the mathematical activity of students using robots. Finally, Problem 4 is about topics related with affin function, such as y-intersect, slope and the relation between the graphic of that kind of functions with the graphic of the function of direct proportionality 'associated' to the first.

The robot travel

Now we present part of a problem that has been solved by students:



1. We asked Pedro and João to imagine and draw a graphic that represents a robot travel from a certain start. They presented the following graphics:

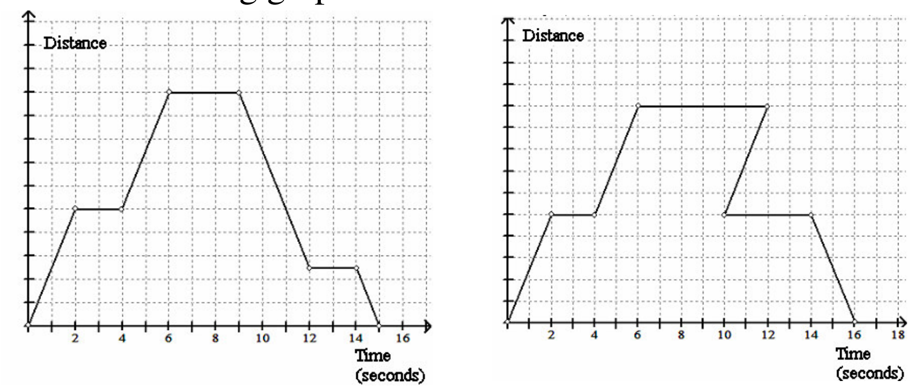


Fig. 1

1.1. Now you have to study the graphics presented by Pedro and João. Describe the robot travel relatively to its distance to the starting point.

1.2. Try to programme the robot in such a way that it realizes the proposed travels. Test it, and, if it is possible, confirm the results. Write the program(s) that you have done.

1.3. Did the robot realize both proposed travels? Present the difficulties that you found in programming the robot to such travels.

1.4. What is the necessary condition in order that one graphic represents the ‘possible travel’?

Description of students practice

Students solved the problems in small groups, collaborating in problem solving, arising hypothesis and discussing their viability. Below we present a transcription[v] of part of a class where students were solving question 1.1.

Rui: Teacher…Teacher… This graphic is not good! [Pointing to the second graphic]
Teacher: It’s not good? Why?
Rui: It’s not good because in this way the robot is walking backwards. And the robot has always to go ahead.
Teacher: I do not understand what you mean [trying that Rui made explicit what he was thinking]
Rui: I don’t know …
Rui looked to the graphic again and goes back to the discussion with the other group elements.
Rui: Teacher… we already know. Could you, please, come here?
Teacher: Yes?
Rui: This line is not what the robot route. It’s the distance.
Teacher: Distance?
Rui: The distance from the starting point. And here is time. And we can not do that.
Teacher: What can’t you do?
Rui: The robot can’t do this route.
Meanwhile, Ricardo [a student of another group that was close to Rui’s group and very attentive to the discussion] answered:
Ricardo: Can’t be because the robot cannot walk backwards in time.
Teacher: What will happen if the robot walks backwards in time?
Rui and Ricardo [almost at the same time]: I don’t know.
Teacher: Observe and study the graphics.
A few minutes later…
Rui: I already know! I already know! The robot had to be at to places at the same time, isn’t it teacher?
Rui (to the group colleagues): It’s not necessary to program this travel because it’s impossible.
Ricardo: It’s true. Let’s go…after all it’s easy.

In Rui's group the solution of question 1.1. emerged only of the analyses of the graphics. The same happens with Ricardo's group, maybe because these two groups were very close on physical space, and listened the discussions among elements of the groups and between those and the teacher. In other groups to programme Pedro's travel was important to understand the graphic; to understand that the graphic is not translating the route of the robot but the relation between time and distance in the travel done by the robot. The work with the first graphic allowed students to understand the second graphic and consequently, to capture intuitively the concept of function.

When every group had solved the problem, teacher discussed with all the group mathematical ideas involved in the problem trying that, they together, make a synthesis of the main mathematical concepts.

In all this process of solving the questions a shared repertoire emerged. The vocabulary they used to approach problems and questions is a mix of vocabulary of two distinct domains (mathematics and robots). They are analysing a graphic but they talk about what a robot can and cannot do. Using the robots and its programming as a taken-as-shared resource allow students to negotiate meaning among them (in the group) and between the group and the teacher and give meaning to students mathematical activity.

To have a join enterprise (that can be to solve the question, to please the teacher, to understand the meaning of mathematical concepts involved or only to play with the robots) is very important to motivate students to engage in the activity and is an integral part of students practice.

The co-definition of mutual engagement is visible through:

- a growing sense of responsibility in solving the questions posed by the teacher and in understanding what they are doing together and what is the meaning of what they are doing;
- not giving up until they found the problem solution;
- a pleasure in going deeper into their ideas and in building a solution to the problem and meaning to their answers.

In these three dimensions of the practice we talk about meaning. In fact Wenger (1998) argues that the social production of meaning is the relevant level of analyses for talking about practice.

But when meaning is discussed in the sphere of mathematics education usually it concentrates on the meaning of (mathematical) concepts. Questions such as the following become important: What sort of meaning can be associated with certain mathematical concepts? What is the meaning of particular concepts to students? What sort of meaning can be associated with this concept from a mathematical point of view? What is the meaning of this concept from the perspective of the teacher? What is the shared meaning of this concept? (Skovsmose, 2005)

Findings

To analyse students practice in mathematical classes is fundamental as element that helps to understand learning. It is important that students' engagement in school mathematics activity is not only to accomplish a curricular programme but that they have a genuine interest by the domains they work and the use of robots have a relevant role as a mediator element in all this process.

In spite of we are now in an initial phase of data analyses we can already foresee some findings that show themselves as promising.

- Students felt comfortable both when building robots and using programming environment.
- Using robots in mathematics class promotes an increment either in discussion between students and between students and teacher and in collaboration on the resolution of proposed problems.
- Students recognize impossibility of executing a task without assuming it as an inability of them. This fact was evident, for instance, at the time when they are solving the previous described problem.
- Function concept was apprehended in a significative way. The definition of function emerged as a final conclusion of students work and not as a starting point.

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[iii] These robots are used at classrooms because students can interact with mechanical parts and see results immediately. This allows students to employ certain theoretical concepts and to understand how they work in reality. It is important to point out that it is not necessary to have prior knowledge in robotics neither in computer programming.

[iv] The term *practice* is sometimes used as an antonym for theory, ideas, ideals, or talk. In Situated Learning theories that is not the idea. In Wenger's sense of practice, the term does not reflect a dichotomy between the practical and the theoretical, ideals and reality, or talking and doing. The paper extension does not allow the development of the idea of practice. For discussion of practice related with mathematics education see Fernandes (2004).

[v] In this transcription (due limitations of space) we mainly present students exhibiting the result of the discussion they had on the group to the teacher. We choose to cut the episode in this way because we can 'see' on the transcription students building, intuitively, the concept of function.