THE EMERGENCE OF AGENCY IN A MATHEMATICS CLASS WITH ROBOTS

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In this paper we will discuss and analyse students' participation in a mathematics class when using robots to think about the mathematical concepts. Our aim is to highlight the emergence of students' agency in the interplay with robots and discuss the role of agency in participation and in the learning of mathematics.

INTRODUCTION

Learning mathematics can be understood as participation in social practices (Lave & Wenger, 1991), where people get engaged in solving problems and making sense, use mathematical representations, concepts and methods (Boaler & Greeno, 2000). As such, analyzing students' participation in mathematics classes becomes important when we want to understand and discuss learning as a phenomenon emerging from participation in social practices. In this paper, we are not interested only with whether or not students participate but how they are given opportunities to participate and how they take advantage of them.

Both Situated Learning Theories and Critical Mathematics Education discuss the learning process as something in which the person must act in order to learn. Alrø and Skovsmose (2002), for instance, explore the idea of learning-as-action in which action can be associated with terms like aim, decision, plan, motive, purpose and intention. That is, "action presupposes both an involvement of the person and an openness of the situation" (p.43). On the other hand, school mathematics classes which allow students to engage in practices of negotiation and interpretation, using physical and discursive tools and resources, provide learning scenarios in which students participate by adapting to the constraints and agreements of it (Greeno & MMAP, 1998).

Through the project DROIDE II[1] – we have created learning scenarios (Wollenberg, Edmunds & Buck, 2000) in which robots are physical artefacts with which students think during school mathematics practices. Our aim is to understand how students produce meanings and develop learning of topics and mathematical concepts when robots are mediators' artefacts.

In this paper we will analyse students' participation in mathematics classes, amidst the scenarios created where robots had a central role, discussing the role of agency in the learning of mathematics.

ON AGENCY

> An individual's agency refers to the way in which he or she acts, or refrains from acting, and the way in which her or his action contributes to the joint action of the group in which he or she is participating. (Gresalfi, Martin, Hand & Greeno, 2009, p.53).

According to our understanding, individual agency relates dialectically with structure, and it is a dynamic competence of human beings to act independently and to make choices (Andersson & Nóren, 2011). Agency is not born with the person.

Giddens (1984) argues that agency is the capability to make the difference and that it relates exclusively to humans. Artefacts are only "allocative resources that influence social systems only when incorporated in processes of structuration" (p.33). Latour (1991) offers a concept of agency that is not restricted to human actors. He coined de term *actant* in order to allow the association of agency with humans. Doing this, he opens the space to conceive agency as something that can be allocated not only to humans. Indeed, if agency is the capability to make the difference then the machines also can exhibit forms of agency. In actor network theory, agency is not restricted to humans but is also attributed to technologies (Rose & Jones, 2005).

Material Agency

Pickering (1995) made a distinction between human agency and material agency. Humans are active and intentional beings. Human agency has an intentional and social structure and intentionality is what makes the difference between human and material agency. Physical artefacts are essential for the modern world. People manoeuvring in the field of material agency "capture, seduce, download, recruit, enrol, or materialize that agency, taming and domesticating it, putting it at [their] service, often in the accomplishment of tasks" (Pickering, 1995, p.6). Human agency is itself emergently reconfigured in its engagement with material agency.

> There is no way that human and material agency can be disentangled. Or else, while agency and intentionality may not be properties of things, they are not properties of humans either: they are the properties of material engagement. (Malafouris, 2008, p. 22).

Pickering (1995) made a distinction, when he developed the terms conceptual and disciplinary agency, in his socio-historical analysis of a case of research in mathematics. Mathematicians "exercise conceptual agency when they engage in decision making, exploration, and strategizing" (p. 53).When they decide to use an established method, agency is turned over to the discipline.

According to Pickering (1995) what generally happens in physics and mathematics is "a dance of agency" that combines the conceptual agency with the disciplinary agency, or the conceptual agency with the material agency.

Critical Agency

Alrø and Skovsmose (2002) presented the idea of critical learning of mathematics. This idea entangles the notion of agency. Although the word "agency" was absent in

Skovsmose's work until 2012, it has been implicitly present in expressions such as intentionality, action, reflection and choice used in his work (Anderson & Norén (2011).

Greer and Skovsmose (2012) think of *Critique* in terms of "critical agency" signifying that critique refers to both reflection and action. The concept of critical agency entangles the dialectic between reflection and action. And the genesis of critical agency lies on the ability and dispositions to imagine that things can be different (Skovsmose & Greer, 2012).

When we want to discuss the critical learning of mathematics, action appears as a fundamental notion and can be associated with expressions such as aim, decision, motive, and intention. This presupposes an engagement of the person. On this conception of learning, intention and action are strongly connected as well as in the notion of human agency.

Alrø and Skovsmose (2002), with the aim of discuss in dept the notion of critical learning of mathematics, also introduced expressions such as intention, reflection and critique. They tried to clarify the dialogic basis of critical learning (of mathematics) in terms of intention and reflection: "While intention refers to the involvement of persons, reflection refers to considerations carried out by persons" (p.157). To participate in a dialogue, in a way that promotes learning, presupposes engagement and this engagement can be characterized in terms of the notion of intention:

> Intentions-in-learning are essential for the students' ownership of the learning process. […] In order for the dialogue to continue, it is important that the intentions of the participants are continually modulated and adjusted to each other. (p. 157).

But students in the classroom have others intentions than those related with the learning of mathematics. They may have intentions of being noticed by the teacher or to sit next to their best friend, and the like. These are the underground intentions. But these intentions are intentions too and consequently they are part of the acts, but not of the learning acts (of the official classroom activity).

There are, according to Alrø and Skovsmose (2002), the resources of intentions. Intentions are formed based on experience, impressions, prejudices, preferences, etc. These resources of intentions are called dispositions. The disposition of the person is the raw material for their intentions and is seen as individual but also as a feature of the person's culture. When we think about learning-as-action, the notion of dispositions is used to describe the source of motives that students have to engage in the learning process.

> "The student's dispositions for learning are thus indicative of the factual possibilities that the student holds for the school system and of the student's interpretation of these possibilities. Correspondingly, the student's dispositions make up a heavily structured framing condition for intentions-in-learning. The

students expose such intentions in patterns and according to their notions about learning and going to school." (p. 160).

Peoples' intentions reflect, to a large extent, their foreground or the foreground of a group of people to which they belong. Foreground can be understood as the way people interpret their possibilities given a certain political, cultural and economic context and their social position in it. Thus, the foreground refers to the person's perspective (Skovsmose, 2005). As a result, the foreground of people should be considered when interpreting their actions. The background must also be taken into account. Both influence what a person might want as well as person's possible actions. Both represent resources of intentions (including underground intentions).

METHODOLOGY

In this article we adopt a qualitative mode of research, because our aim is to develop an understanding of human systems. In this case the system composed by a technology-using teacher and his or her students and classroom (Savenye & Robinson, 2004).

To use Situated Learning Theories as a theoretical foundation implies some methodological assumptions such as assuming that investigating is to participate in a wide range of practices in which the investigation occurs (Matos & Santos, 2008). That was the positioning assumed by the researcher involved in the data collection. As a participant in the research, the researcher also learned. So, the participant observation was a central strategy and acquired the status of data collection methodology.

The data collection was made in two months, between February and April of the school years 2010-2011. We chose to work with two classes of 7th grade students (ages between 13 and 15 years old) studying functions. There was an initial session where students had their first contact with the robots. It took place in the Droide Laboratory of University of Madeira. A video cam was used, focused on a group. Four 90 minute classes were recorded (also with a video cam focusing in a group).

The analysis was made based on the video transcriptions and on the field notes taken by the researcher and teachers involved in data collection. The units of analysis included person, activity and the contexts where the activity took place.

We have been trying to find patterns of interaction, among students as well as among students and teachers, using Greeno's (2011) ideas about students' interactions because it allows us to explain students' participation in school mathematics' practices and to make visible the positioning students assume concerning agency and accountability (Fernandes, 2012). But we have also been trying to understand students' intentions in order to discuss critical agency. On this paper the findings will focus on a particular case study of a student that will be referred as 'He'.

A SCHOOL MATHEMATICAL PRACTICE WITH ROBOTS

During the initial session, students went to University of Madeira, to the DROIDE Laboratory, to assemble and program robots.

On the following day, back to school, they worked on a worksheet the ‘notion of a function’. The aim was for students to work with robots, oriented by the questions of the worksheet, and understand, learn and define the concept of function. It took two 90 minute classes. The worksheet had a closed and very scholar structure. The innovation was the inclusion of the robots to think about the mathematical concepts involved. Each group of students received a worksheet and, even before robots were distributed, the teacher asked them to read attentively the issues on the proposal.

The task consists in analysing two graphics depicting two robot trips. Firstly, students had to make a description of the robot trip having the starting point as a reference. The second question was about the robot`s programming in order to realize the trips, if possible. The graphics presented were the following:

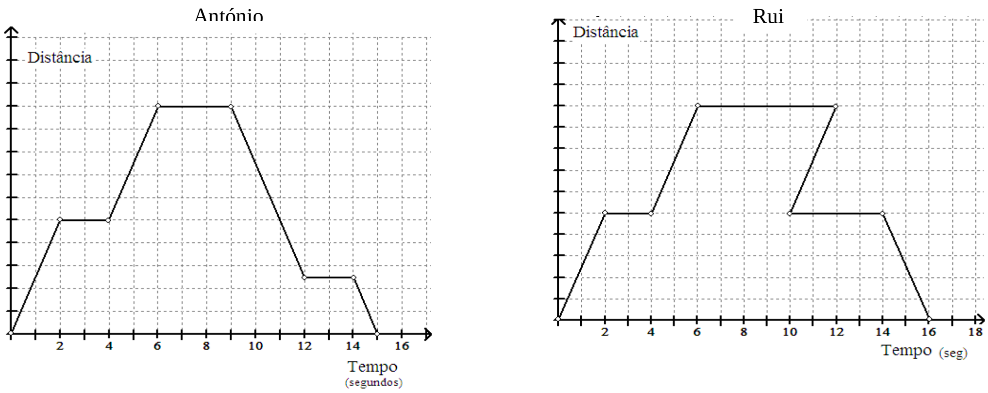

Figure1 – Graphics presented on the worksheet

The school mathematics practice analyzed can be characterized by the resolution of mathematical questions in groups, in which students had to discuss every task, to describe the processes that leaded them to results and finally students’ presentation of the results and conclusions to the rest of the class. The wider group discussion was mediated by the teacher.

‘He’ was one of the 10 boys that had failed the preceding year and during this school year only had a marginal participation in mathematics classes. Since the moment he began to work with the robots, ‘He’`s posture, in mathematics classes, changed. ‘He’ was the one handling the robot in the group, programming it and checking the programming results. It seems that robots made ‘He’ able of imagining that things can be different.

‘He’`s group read the graphic concerning António`s trip (on the left side) with few hesitations. After analysing António`s graphics and programming the robot to make that trip, experimenting it on the floor and verifying if it is well done, they came back to the desktop and asked teacher's help.

He: In the second graphic we don`t really have to do anything, right?

Teacher: Why do you say that? What do you mean by "don't have to do anything"?

He: We already analyzed Rui's graphic and we can't program it.

Teacher: And why can't you?

He: We can't because there's no command that allows us to make the robot go back in time.

Teacher: But where in the graphic do you see that the robot has to go back in time?

He: Right here teacher (He pointed the graphic to the 12s moment), at 12 second the robot was at a distance 10, but also at a distance of five, because the robot went back and time does not go back. It can't be at two places at the same time. We can't program it because it isn't possible.

'He' was very much convinced that this programming wasn't possible. Even so, he couldn't convince his colleagues that were not, at the time, able to see his point. After discussing his point of view with the teacher (may be with the intention of showing her what he can do with mathematics now) he left his colleagues to proceed with the task of programming the second trip even knowing it wasn't possible, as he pulled aside and started writing. After some time, the teacher went back to the group and asked if they already had reached to a conclusion. One of students in the group replied:

Pe: Yes we did. We can't program it. We only made it until here (pointing on the Robotics Invention System programming interface, to the path until the 12 second).

The inclusion of the robots motivated 'He', opened a space of factual possibilities that 'He' held and made him committed to the resolution of the working proposal. He convinced the teacher but not his colleagues. Probably due to the way other students saw 'He' in terms of mathematical knowledge. He was a student with marginal participation and maybe because of that his mathematical explanation wasn't accepted by the group. It was not supposed that 'He' was accountable to the solution of mathematical question due to his trajectory in mathematics classes along all the school year until robots arrive.

'He''s questions to the teacher were very useful for two reasons: (i) in order to include the teacher in the accountability system, as the person who could convince the others students of the group, once he wasn't been able to convince them (ii) in order 'He' shows to the teacher what he was mathematically capable of doing (accountable for). These are 'He''s underground intentions. After solving every other question of the worksheet, which included writing the condition needed to allow for a correspondence to be a function, students had to comment on the following sentence "The correspondence presented by António is a function. Rui's correspondence isn`t a function"

'He' again asked the teacher a question, for what he already seemed to have the answer, showing once again what they had been able to achieve making himself accountable to the idea.

He: Teacher, can we say that Rui's graphic isn't a function because there is one single time corresponding to two distances?

Teacher: And that's what can't happen for a trip to be possible?

He: Yes it is. For a trip to be possible, it can't be at the same time at two different places. Rui's robot at 10s is at the distance of 5 and 10.

'He' was the 'motor' of this group for the 'good' resolution of the mathematical question proposed, displaying his conceptual agency, that was emergently reconfigured in its engagement with material agency. Using the robots by which he showed great interest since the first session, seemed to be the starting handle to operate the change on 'He' participation on mathematics class. In this episode we can see some reflections of 'He', probably provoked by the introduction of the robots. He was able to explain why the correspondence was not a function in terms of the robots' functioning "[the robot] can't be at two places at the same time". The robot, associated to the notion of function, was part of the shared repertoire of this class. The students used that sentence every time they have to justify that a correspondence is a function and after they 'translated it' to the situation they had to solve.

Two classes after, students worked on the notion of "proportionality[2] as a function". The first question of the task was to compare the speed ot two robots and to discuss if time and distance were in proportion. They have to program the robot to move forward for 1second and then measure the distance covered by the robot; and then to do the same thing for 3 and 6 second. After that they have to calculate the quotient between distance and time and then to conclude about proportion. The group of 'He' has done for 1 second, and after doing for 3 seconds, 6 seconds, twice, 'He' said:

He.: It cannot be. The robot moved again 110 cm. I'll ask the teacher.

Fi.: I can't understand why you say it's not correct. We have already measured twice and it gives the same value and not 138cm as you want.

He.: You only have to do calculations. Do it!

Fi.: What calculations?

He.: 46 times 3…

Fi.: is 138.

He.: It is because of that that I say that it should be 138.

Pe.: Ah! Now I understand… we have to multiply the first value by the second

He.: Exactly. If in one second ‘Tank’ moved 46cm, times 3 is 138 e for 6 is 276… and this is not what we obtained…measuring.

In this episode we can see the difference of posture from the group colleagues to ‘He’. ‘He’ was accountable to and accountable for by the colleagues. The different participation of ‘He’ on mathematics class gave him mathematical authority. Now colleagues listen and ask him to explain what he is saying.

[After that, teacher arrived to the group, listened all the students’ complains about what is not going well, and said:

Teacher: Assuming that you measured correctly, try to think about reasons to justify the difference between what should be and what it really is.

In the students’ discussion about the reasons for that, emerged justifications such as: the ground is not completely plan, robots’ batteries had spent, braking time is different for different robots, etc.

It is interesting to see that students that had had a marginal participation now are able to reflect on mathematics. Robots brought to several students motives and disposition to engage in the learning process. This engagement made the difference on the kind of participation assumed by those students. ‘He’ and several other students, most of them ‘disposable’, in Skovsmose’s (2005) sense, held that possibility from the school system.

During this work with robots, teachers were invited to organize a workshop to some classes of the school. We (researcher and teachers) decided to invite some students to do it for the colleagues. ‘He’ was one of the invited students. When we were in a meeting to prepare the workshop, ‘He’ asked:

He.: Teacher, is it possible to know for which classes we’ll do the workshop?

Teacher: It’s not important. There are colleagues from the school.

He.: But … I would like to know if 8º2 (the class he belong the preceding school year) will be…

Teacher: No. 8º2 will not be.

On the following day ‘He’ did not come to the workshop.

On the following mathematics class teacher asked him why he didn’t come to the workshop. First he said that the alarm clock didn’t went off and then, after a pause of some seconds he added that he wasn’t interested in teaching robots to school colleagues that he didn’t know well. When researcher talked with him (informal interview) he explicitly recognized that it will be interesting to teach the colleagues that ‘know more than me …because they are on the 8^{th} grade’.

‘He’ seems to have the expectation of showing his colleagues of the preceding school year class, where he has not been successful, that now he is. This scenario did not occurred, so ‘He’ did not activated intentions to participate on the workshop and gave up. This intention of ‘He’ reflect his foreground. Analyzing his attitude without taking it into account can generate a conflict between teacher and ‘He’.

FINAL CONSIDERATIONS

To introduce robots on this learning scenario made agency to emerge on students that usually have a marginal participation. These students acted on the field of material agency, brought by robots to the created scenarios, captured this agency and placed it in service of the task they have to carry out (Fernandes, 2012). Human agency was reconfigured in its engagement with material agency (Pickering, 1995). ‘He’’s work with robots changed his participation in mathematics class and also his group colleague’s participation.

Some students, such as ‘He’, saw in robots the possibility to imagine that it was possible to be successful on mathematics class and they grabbed it. Thus, robots displayed, in students, intentionality to engage on the learning process and made them to reflect on the learning process.

Analysing students’ participation without paying attention to their background and foreground can lead to a narrow view of the learning of mathematics.

NOTES

1. The research reported in this communication was prepared within the project DROIDE II – Robots in Mathematics and Informatics Education funded by Fundação para a Ciência e Tecnologia under contract PTDC/CPE-CED/099850/2008.

2. After several tests we verified that the time that the robot needs to reach the standard velocity, as well as, the braking time, are negligible. So we can assume that, to the end of this question, time and distance covered vary in proportion.

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