

# **‘ROBOTS CAN’T BE AT TWO PLACES AT THE SAME TIME’: MATERIAL AGENCY IN MATHEMATICS CLASS**

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*This article aims to discuss the role and impact of robots on mathematics learning. Analysing students’ participation in mathematics classes, when using robots, we discuss their agency and its role on fostering participation and consequently on the learning of mathematics<sup>i</sup>.*

## **INTRODUCTION**

Learning mathematics has been traditionally seen as a cognitive and individual activity and mathematics itself as the subject for the mind. The conception of learning we talk about in this article is considerably different. We consider learning mathematics as an aspect of participation in social practices (Lave e Wenger, 2001) in which people get engaged in solving problems and making sense, using mathematical representations, concepts and methods (Boaler e Greeno, 2000).

This idea of learning goes beyond the idea that social practices make rich contexts for learning mathematics - it defends that being part of social practices is what learning mathematics is. 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 – we have created learning scenarios<sup>ii</sup> in which robots are physical artefacts with which students think during school mathematics practices, aiming to understand how students produce meanings and develop their learning of topics and mathematical concepts when robots are mediators’ artefacts.

In this article we will analyse students participation in mathematics classes, in the sphere of the scenarios created, discussing the role of material agency in the learning of mathematics.

## **LEARNING AS PARTICIPATION IN SOCIAL PRACTICES**

Learning is a process that takes place in a participatory structure (Lave e Wenger, 1991). This means, amongst other things, that learning is mediated by the different perspectives existing between co-participants.

The focus of Wenger's (1998) theory in his book *Communities of Practice – Learning, Meaning and Identity* - is in 'learning as social participant'. Participating does not only refer to events of local engagement in a certain kind of activities or with a certain type of people, but to a wider process of being an active participant on the practices of social communities. That participation makes us not only what we are but also who we are and the way we look and interpret what we do. It also shapes the communities in which we participate; in fact, our ability or lack of it to shape our communities of practice is an important aspect of our participating experience.

Participation in a social practice implies constant negotiation. To negotiate a shared enterprise implies responsibility among the parts involved. This relations include what matter and what doesn't, what is important and what isn't, what to do and not to, what parts need attention and what to ignore, what to say and not to, what should be justified and what to presume justified, what to show and what to conceal, to understand when actions and artefacts are good enough and when they still need improvement or refining.

### **Learning as participation in mathematics classes**

Analysing students' participation in mathematics classes becomes important when we want to understand and discuss learning as an emergent phenomenon from participation in social practices.

Learning mathematics is a process of people becoming more capable of participating and a social practice which encompasses the relations between people and knowing. Boaler and Greeno (2000) consider knowing and understanding mathematics as aspects resulting from participation on social practices, in particular, in those which the individuals engage themselves on making sense and solving problems using mathematics representations, concepts and methods as resources. Throughout this process many moments of negotiation take place. These moments of negotiation that occur in mathematics classes shape the practice of school mathematics, affecting participants and their way of participating.

Recently Greeno (2011) has been elaborating about students' interactions and stated that we can analyse the way students position themselves in the interaction by two ways: the systemic positioning considering the other students and the teacher; and the semantic positioning considering the concepts and the mathematics methods. The systemic positioning implies the levels of expectations of others to who is expected to be the first to contribute, to question other's proposals and to whom to explain about the methods and processes involved in the tasks. The semantic positioning implies what Pickering (1995) called conceptual agency, in which the individual makes choices and emits judgements based on the meanings and adaptation of methods and interpretations.

To think about the systemic position we can analyse two aspects: the negotiated structure of participation and the way students understand the proposed task.

To explain the negotiated structure of participation we will focus on question such as: (i) how is one idea appropriated by the collective? (ii) Who is expected to assume or criticise the mathematics ideas? (iii) How do students become encouraged to speak with each other, meaning, what rules of argumentation are at stake in that practice? To explain the way students understand the proposed task we will focus on: on the sense-making requirement, the task's structure and on the requirements to fulfil the task with success (Gresalfi, Martin, Hand, Greeno, 2009). These aspects were the focus of our analyses because analysing these aspects of the interaction allows us to explain students' participation in school mathematics practices and to make quite visible the positioning students assume concerning agency and accountability.

### **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”(Gresaldi et al, 2009, p. 53).

Pickering (1995) made a difference between human agency and material agency. Humans are active and intentional beings. Human agency has an intentional and social structure. Physical artefacts are essential for the modern world. People manoeuvre in a field of material agency "capture, seduce, download, recruit, enrol, or materialize that agency, taming and domesticating it, putting it at our service, often in the accomplishment of tasks"(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, that is, of the grey zone where brain, body and culture conflate”.(Malafouris, 2008, p. 22).

Pickering (1995, in Gresalfi et al., 2009) made a distinction, when he developed the terms conceptual and disciplinary agency, in his sociohistorical 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 happens generally, in physics and mathematics, is ‘a dance of agency’ that combines the conceptual agency with the disciplinary agency or conceptual agency with the material agency. Pickering did not consider material agency significant in mathematics (Wagner, 2004). Although Pickering rejects the possibility of material agency in mathematics, Wagner (2007) considers that question should be pursued. In this article we'll discuss how is this dance between the material agency and conceptual agency or disciplinary agency in mathematics classes.

## **METHODOLOGY**

The nature of the research related in this article is qualitative due it aims to develop an understanding of human systems, such as a technology-using teacher and his or her students and classroom (Savenye and Robinson, 2004).

To use the Situated Learning Theories as theoretical foundation, when doing research, implies some methodological assumptions such as assuming that investigating is to participate in a wide range of practices in which the investigation occurs (Matos e Santos, 2008). That was the positioning assumed by the researcher involved in the data collection. To be part of the research was also to learn. So, the observant participating 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 the 7<sup>th</sup> 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 notes taken by the researcher and teachers involved in their project notebook. The units of analysis include person, activity and the contexts where activity takes place (Matos, 2010). We tried to find patterns of interaction, among students and students and teachers, using questions above to think about data. Bellow we present a short part of the analyses that we have been doing.

## **DISCUSSION –THE CASE OF ‘HE’**

The initial session, students went to University of Madeira, to the DROIDE Laboratory, to assemble and program robots. Students were made accountable to the assembly of a robot that could be programmed and that could function as they were eager to see the robot (a car) moving. They had to convince themselves and other groups and teachers that they were capable of doing it, by simply doing it, even because despite the great ambience, cooperation and companionship there was a certain competition going on to see who would be the first group to finish the project and who would do it better. There wasn't any type of explicit negotiation as they worked thru building the robot or programming it. Each element of the group has taken on a task and the others simply assumed another task or function.

On the following day, back to school, they worked on a worksheet 'notion of a function' which aim was that students working with robots, oriented by the questions of the worksheet, understand, learn and define the concept of function. It was been made over 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 is to think about two robot trips given two graphics. The first question was about students analysing both graphics and 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 realize the trips, if possible. The graphics presented were the following:

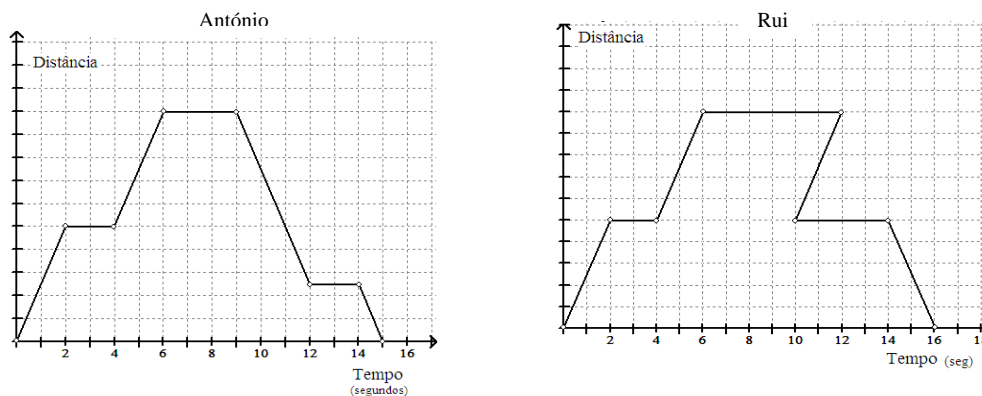


Figura 1 – Graphics presented on the worksheet

The school mathematics practice analysed can be characterized by the resolution of mathematical questions on group, in which students had to discuss every task, to describe the processes that led them to results and finally they had to present 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 this school year had had a marginal participation on 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.

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

He: In the second graphic we don't really have to do anything, right?

Teacher: Why do you say that? What do you mean "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 (Rui 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 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' and made him to commit to the resolution of the working proposal. His point of view has 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 his trajectory in mathematics classes along all the school year until robots arrive.

'He's' questioning to the teacher was very useful in order to include the teacher himself in the responsibility system, there is, if teacher approved his answer, the other students of the group will be convinced, once he wasn't being able to convince his colleagues. But it was probably a way for 'He' to show what he was capable of (accountable for). After solving every other question of the worksheet, that 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 mathematical question proposed, displaying his conceptual agency, that was emergently reconfigured in its engagement with material agency<sup>iii</sup>. Using the robots by which he showed great interest since the first session, seemed to be de leverage to operate the change on 'He'.

He was able to explain why the correspondence is 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 seeing that they always used those 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.

## **FINAL CONSIDERATIONS**

During these classes there were times where mathematics contents assumed some invisibility in order to provide the robots with some more visibility and there were times where the robots or even its programming allowed mathematics contents a wider visibility. The duality among visibility and invisibility of the artefacts (physical and conceptual) shaped the participation and by that, students mathematics learning.

Introducing robots in the school mathematics learning scenarios displayed a dynamic link between the work with these artefacts and the way that students think about the notion of function. The agency emerges from the action of using robots to think mathematically. We need to recognize that material agency is irreducible to human agency. Nevertheless, we need to stress that the trajectory of emergence of material agency is bound up with that of human agency (Pickering, 1995). In this case, it displayed conceptual agency in a student that usually uses to do almost nothing in mathematics class.

Students thinking about the notion of function with robots displayed a dynamic coupling between dealing with the mathematical concepts and dealing with the robot that looks like a dance of agency. We have to underline that the dance is between equal partners. This equality does mean that one of the two dancers is not at times leading the dance. What it does imply is that we can not separate both thinks. We can not separate what has been learned from the action of dealing with robots. Trying to separate it is like ‘trying to construct a pot keeping your hands clean from the mud’. Agency is relational and emergent product of material engagement (Malafouris, 2008). Robots were determining on the kind of participation that students had, on there material engagement and material agency is strongly coupled with conceptual agency displayed on students.

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<sup>ii</sup> The concept of learning scenarios adopted in this article was stories of what might be. Unlike projections, scenarios do not necessarily portray what we expect the future to actually look like. Instead scenarios aim to stimulate creative ways of thinking that help people break out of established ways of looking at situations and planning their actions (Wollenberg, Edmunds & Buck, 2000)

<sup>iii</sup> Thru several classes working with robots 'He' was been accountable to and accountable for by the colleagues and by the teacher. There is no space for these analyses on the pages of this article.