Teachers' talk about Robotics: Where is the Mathematics?

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Programming and the use of robotics present affordances for mathematics learning with application across a broad range of ages. However, realising these affordances in the classroom requires educators to recognise and build apron these potential opportunities for learning. This paper reports one component of a larger study, examining teacher discourse in semi-structured focus group as they review engagement with robotics. Data highlights limited engagement in mathematisation and the key role of mathematical pedagogic content knowledge (PCK).

Background

Robotics in Mathematics Learning

The use of robotics and programming has a long-standing history in mathematics education with tools such as 'turtle' geometry or Logo explored in classrooms for over three decades. Here, research suggests that children engaging with programming robots to move have opportunity to explore spatial concepts, problem solving, measurement, geometry, and engage with meta-cognitive processes (Clements & Meredith, 1993; Yelland, 1994). Papert's seminal work in this area suggested that Logo programming, and the visual nature of this tool, was a way to "externalize" learner's ideas and make concepts "more accessible to reflection" (Papert, 1980, p. 145). The visual nature of these tools, and the use of dynamic representation enables engagement in mathematics learning and opportunities for exploration of both content within mathematics and processes of mathematics learning.

A growing number of studies promote the use of robotics in engaging children in problem solving and learning (Bers, 2010; Bers & Ettinger, 2012; Bers, Seddighin & Sullivan, 2013; Horn & Jacob, 2007; Horn, Solovey, & Jacob, 2008; Horn, Solovey, Crouser, & Jacob, 2009; Sullivan & Bers, 2012). These studies suggest that robotics can be engaging learning opportunities (Kazakoff, Sullivan, & Bers, 2013; Stoecklemayer, Tesar, & Hoffman, 2011) and promote collaboration and problem solving, with tangible interfaces and hybrid graphical-tangible tools enabling participation both younger and older learners. Highfield's research, using simple robotics with young children, suggests a range of mathematical content that can be explored and highlights the key role of the task in promoting mathematics learning (Highfield, 2010; Highfield & Mulligan, 2009). Goodwin and Highfield (2013) suggest that the manipulable nature of these tools affords opportunity for problem solving and reasoning; with the task at hand, combined with the tool, enabling mathematical thinking. However, robotics alone do not enable mathematical engagement, with the key role of the educator, the task, and the context of learning also playing integral roles in extending mathematics learning.

Pedagogical Content Knowledge for Teaching

The role of the teacher in mathematics learning is essential, with research suggesting the intersecting domains of pedagogical knowledge, and content knowledge as particularly key in mathematics learning (Ball, Thames, & Phelps, 2008; Hill, Ball, & Schilling, 2008). While a teacher of mathematics must know how to solve the problems they provide to their students,

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such knowledge of content alone is insufficient. A teacher of mathematics must also know how to represent a solution to such a problem with a picture, explain why the solution works, and identify common mistakes made by students as they solve such problems (Hill, Rowan, & Ball, 2005; Hill, Blunk, Charalambous, Lewis, Phelps, Sleep, & Ball, 2008). Thus, pedagogical content knowledge is comprised of both knowledge of content and pedagogy, and would be displayed by one knowledgeable of the best ways of representing some concept for students, as well as the ability to explain such concepts in order to address students' conceptions (Schulman, 1986).

Ethnomathematics as a Tool to Examine Mathematical Engagement

Savard's (2008) ethnomathematics model presents different context in the mathematics classroom: mathematical; sociocultural; and citizenship. This framework presents the starting point of a lesson as situated in the sociocultural context, where an object or a phenomenon was studied within a situation. The mathematical modelization of the situation brings students into the mathematical context. The implications of the mathematical results are studied within the sociocultural and the citizenship context. Formulation of results during the classroom discussions can help students develop citizenship competencies such as critical thinking reflection and decision-making (Savard, 2008). Thus, within this robotics project, we studied different contexts in the teachers' discourses to situate their epistemological point of view, as well as opportunities for students to develop their mathematical competencies. The robotics project was considered as the sociocultural context in which the sociocultural objects were studied in order to develop different kind of knowledge.

Given this, the robot itself might be studied using movies, stories or visual arts. The tasks to be performed by the robot, that is, the missions, are also parts of the sociocultural contexts. Coding the robot using mathematics is part of the mathematical context. The citizenship context is interpreted as what is involved living in society, including political, economic, and societal rules. The mathematical context is rich and offers huge potential when it is time to code a robot. However, this could only be realised if teachers were able to recognise and engage with this mathematical context and learning afforded. The study drew on this framework and examined the following research questions:

1. What was the focus of teacher attention when planning and implementing a robotics project in the classroom?
2. To what extent were teachers able to identify and articulate the mathematical context within this robotics project? and
3. How did teachers identify and extend on mathematics learning?

Based on that, we could define the nature of the teachers' sensitivity to the milieu (DeBlois, 2006; Savard, Freiman, Larose, & Theis, 2013) when they used inquiry-based learning to integrate mathematics in the robotics project. The teachers' sensitivity to the milieu might be defined by what teachers are paying attention to when planning, teaching, or evaluating students.

Methodology

The robotics project took place in September 2010 and ended in June 2011. Six French Canadian elementary school teachers from Grades 1 to 6 volunteered and registered for this project offered by their School Board. The School Board provided all the robotics material. In addition, two mathematics consultants and two computer technology consultants provided training and support for the teachers. The training and the support were provided over six days of meetings through the school year with computer technology consultants and mathematics education consultants alternating presentation and attendance at meetings.

Within this project the researcher acted in the role of mathematics consultant and conducted the semi-structured focus group.

The project focused on two main points of data collection including: (1) data collected from the classroom context, including teacher plans and robotic tasks, referred to as "missions"; and (2) a semi-structured focus group with the teachers was also conducted to explore teachers' implementation of the project in their classroom. This paper refers only to this second data component. Within the focus group, teachers began by discussing how the robotic project was conducted in their classrooms, more specifically outlining what they did with their students. The discussion was held in French. This discussion was video-recorded and transcribed by a research assistant and translated into English. The teachers' discourse was analysed using the afore mentioned framework (Savard, 2008) to explore teacher's sensitivity to the mathematical context and to mathematisation of learning with robotics.

Results and Analysis

Through the discussion among elementary schools teachers, three School Board consultants, and the researcher, two milieus emerged from our corpus of data.

The First Milieu: Learning Opportunities for Students

The first milieu that emerged from our data is related to the learning opportunities for students. The robotics project enabled students to learn about and use different kinds of robots, to explore and their use as well as constructing and programming robots using *Lego NXT* or *Lego WeDo*. The learning opportunities are in fact activities that are related to the content to be learnt within the robotics activities. Along with technologies, those teachers identified mathematics, language arts, and visual arts as content to be learnt by students.

For technologies, teachers mention robots as one item of content. Here, they wanted students to learn about robotics, especially what makes a robot a robot, such as sensors. They also paid attention on how to program or code the robot, using a computer-program. As one teacher stated:

> Then, I went to the computer lab to look at the program SCRATCH with the students, looking at the different colours, controls and movements. (Grade 1 teacher Sophie).

Mathematics was an articulated goal for some teachers when using the robotics with students. First, the tasks involved mathematical knowledge such as geometry and measurement. For example, in Grade 6, the robot had to do a path made of square of one-meter squared or a rectangle where the lengths needed to be double the width.

Then, there were some mathematical concepts needed to code the robots:

> Just before the holidays, I showed them the program on the board and the little presentation. I created four small missions, for example one of them was to make the robot move forward in a straight line for a meter. For the second mission, the robot needed to turn by a quarter. We worked on that in Math, the rotations by a quarter to the left or right. The second mission was only on rotation, then I had planned to make them do a square, but we did not get to that. (Grade 4 teacher Priscilla).

In the above example, the task outlined facilitated engagement with measurement content, with the teacher demonstrating an understanding of pedagogy and content in mathematics learning, harnessing the robotic tool to facilitate mathematical engagement.

Language arts were also outlined, with some teachers identifying the need to have students know the vocabulary associated with the robot. Thus, students learnt the names of the pieces used for building the robot, because they need this information to build it. In one of the Grade 1 classroom, those words were studied along with the regular vocabulary words:

> I focused really on the vocabulary and the right terms. It is not a thing, but actually a bolt for example. The importance of using the right term, where it is appropriate. (Grade 1 teacher Nancy).

In one Grade 4 classroom, students had to write a story about robots doing mission on Mars. The robotics gave a nice theme to explore for students:

> They will imagine it as if it occurred for real that the robot landed in Mars. Then, many imaginary things would be able to occur. Their robot can even have emotions; we bring the project to the next level. Here we continue by focusing on French and expression. (Grade 4 teacher Priscilla).

In addition to the Language Arts focus, one Grade 1 teacher mentioned visual arts: she asked her students to build a robot in team of two using recycling material as the starting point of the project:

> I started with a Visual Arts activity. I asked them first what a robot was in their opinion, and I also asked them to bring recycled materials that they would use to make their artwork in groups. (Grade 1 teacher Sophie).

The Second Milieu: Learning Conditions

The second milieu that emerged from our data is related to the learning conditions for implementing robotics. Teachers referred to time, material, classroom management, and motivation for students as main learning conditions.

Time was discussed as the length students used to complete some tasks with the robots. It is also related to plan the use of the computer lab, as well as the material. Because students were required to build the robots using Lego bricks, they have to carefully plan the time allowed to it:

> When we are at the point of programming, it is not necessary to do it all at once. Like classifying the pieces, we have no choice, but to do it all at once. The construction part too, I found it hard to cut that part in two. When we do a bloc, we get settled and everything is there, ready to build it all, but for the missions one period and "one flapping time" is enough. (Grade 4 teacher Priscilla).

The material brings also one constraint: as there was not enough material for every student; they had to share the material. This led teachers to talk about teamwork and classroom management:

> It is possible that we do robotics all together, but for the mathematics aspect of it I prefer that they are only two to work on the robot. After that, it was the construction of the robot itself. It was not easy for them to be on the same page and to each respect their own role. You give out the pieces, you build, etc. Half of the students were able, but the other half was not. There was always one that wanted to hold on to the pieces. Teamwork is hard and they do not have the maturity. (Grade 4 teacher Priscilla).

The Grade 6 teacher talked about how students divided the work of building the robot, coding and testing with the robot:

> They assigned each other the tasks, but they rotate. It is not always the same person doing programing; therefore, they each get to try different tasks. (Grade 6 teacher Phil).

Finally, they spoke about how the robotics project motivated students: they were thrilled to work with the robots. As a grade 1 teacher said:

> Yes, boys just like girls were really motivated. They had their eyes wide open. They were eating the information. Afterwards, I presented the robots with a PowerPoint presentation once again. (Grade 1 Teacher Nancy).

The Grade 4 teacher Priscilla expressed how those learning conditions were tied together:

> The first two missions everyone had the chance to complete them. The third one only one team almost completed it. They did not want to stop. It was December 22nd in the afternoon and we were working on robotics. Usually we do other things, but I said that we would work and have fun while working on robotics. They were very happy. Even though they had something hard to do and that they were tired, it went well. But at the end, they could not take it anymore. (Grade 4 teacher Priscilla).

Discussion

Overall, an analysis of dialogue in this focus group indicates that the teachers spent more time discussing the learning conditions than the learning opportunities for their students. Outlined above as the second milieu data from this focus group suggests that teachers were paying more attention to the implementation of the robotics project than the learning process of their students. Thus, those learning conditions seemed very important for them to share among their colleagues. We can look at those learning conditions as important aspects to consider facilitating the learning opportunities. It seems that the pedagogical knowledge for teaching involved was important for facilitate students learning, but it was not directly aimed toward some specific concepts to be learnt, such as addressing students alternative conceptions (Savard, 2014). In this case, the milieu they were paying attention belongs to the citizenship context, where all learning conditions refers to how to live in society: planning time, dividing work, rules and norms as a group and motivation to do something.

When they discussed the learning opportunities for their students, they talked more about the tasks completed than the mathematics concepts to be learnt. It is also surprising that they did not mention learning science and technology at all. While it was evident that teachers could address some arts (languages and visual) around the robots, there were no scientific or technical concepts involved in the projects described with this focus.

Again, the pedagogical knowledge for teaching mathematics present in the discussion was quite superficial. Discussion of mathematical context and mathematical opportunities was limited. The teachers did mention mathematics as a task to be performed by the robot and the role of problem solving as students planned and represented code for the robot to perform the task. Here, the mathematics involved to perform the task, i.e. the robots' mission, can be considered part of the sociocultural context because it is the mission to be performed by the robot. From an epistemological point of view, it does not involve any use of mathematics other than mathematics as cultural symbol or artefact. It could be any symbols on drawn on the floor for the robot roll into. The mathematical meaning given to these representations has to be connected to coding the robot to do that. On the other hand, the mathematics involved in coding the robot is part of the mathematical context because is all about using mathematics to code the robot to perform the task. There is mathematization or modelization of the situation. There are different processes involved and mathematical reasoning is absolutely necessary to code the robot in relation to the task to be performed. In our data, this is missing in teachers' discussion. They knew that the robotics project was about mathematics because they were taught and trained in this direction. But this is what they were less sensitive too. For instance, they did not talk about this knowledge on how to assess it. But it might be because they were not ready yet to think about it in their implementation process. In this case, they were not paying attention at that time. Another reason might be because they are still learning about the robots, how to code and the mathematics involved. Thus, knowing how long the robot needs to rotate in order to follow a path into a maze is not a mathematical knowledge written into the provincial curriculum and thus, they might not be familiar with.

Concluding Remarks

While this study is limited due to its small size and focus on one data set its findings are relevant, highlighting the challenges teachers face in implementing technology in classrooms. Within this study teacher's focus on the use of the tool, rather than on the mathematics learning afforded by the tool suggests. In that case, how can we support teachers to do both?

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