Teachers' perspectives on the use of technology to teach Functions at lower and upper secondary

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This study aims to understand the perceptions of lower and upper secondary age teachers of mathematics regarding the use of technology to teach functions. For that, a mixed methodology was adopted, and the perceptions of 129 teachers were collected through a questionnaire (quantitative section) and four teachers through an interview (qualitative section). The main conclusions point to similarities in teachers' perceptions, but also to some differences related to the level that they taught. Teachers show conviction about their knowledge on technology and about the potential of technology in what concerns their teaching and the students' learning. However, they are not so clear about the best way to articulate technology and paper-and-pencil methods, nor about the use of technology in assessment.

Keywords: Technology, Functions, Teachers of lower and upper secondary, Teachers' perspectives.

INTRODUCTION

The notion of function is one of the most important concepts in mathematics (Mesa, 2004) and technology can make an important contribution to its teaching. Teachers can rely on technology as a source of information to prepare their lessons or use it to get a deeper involvement of the students in the classroom, or even to enhance different forms of assessment. These are a few of the many options available to the teachers when considering the integration of technology with their practice; a practice that we know to be marked by the professional knowledge of the teachers, by their conceptions and by the teachers' teaching context.

In Portugal, the initial training program for lower and upper secondary teachers is the same. As so, studying these two groups of teachers can provide a deeper understanding over the impact of the teachers' professional experience on their practice. In this study, we analyze the perceptions that lower and upper secondary teachers have of the use of technology in the teaching of functions. Specifically, we seek knowledge over the teachers' perceptions regarding: (1) knowledge of technology, (2) technology use, (3) consequences of technology use, (4) technology versus paper and pencil, (5) skill development, and (6) technology and assessment.

In this study, we understand *perceptions* as the ways of thinking, or images expressed by the teachers, when talking about their professional practice. And we assume them as privileged windows into teachers' knowledge and conceptions.

FUNCTIONS AND TECHNOLOGY

According to the Portuguese programs (MEC, 2013), functions begin to be addressed

at the 7th grade (age 12), in the first year of the lower secondary, and continue to be studied in each of the three years of this stage. After this, students continue to study functions at all the three years of the upper secondary school (if the students choose a course that includes mathematics, such as sciences) (MEC, 2014).

In the teaching and learning of functions, their different representations play an important role. In fact, they allow the students to understand in a different way what could not be understood in the initial representation and, as Kaput (1992) says, are fundamental to the understanding of the concept.

One of the potentialities of technology is to allow an easy and fast access to multiple representations (Rocha, 2016), which allows the students to establish or reinforce links in a way that otherwise would not be possible (Cavanagh & Mitchelmore, 2003), enhancing the development of a better understanding of functions, of the notion of variable and of problem solving (Burril, 2008). The connection between different representations creates a global vision, which is more than the joining of the knowledge relative to each of the representations. Additionally, the technology allows a full exploration of the numerical and graphic approaches in a way that until then was not possible, thus favoring an integrated approach of the different representations and consequently the development of a deeper understanding (Rocha, 2016). however, technology allows more than that. It makes possible the modeling of real situations, promoting the understanding of the potential of functions for the exploration and understanding of aspects of the real world.

TEACHERS' KNOWLEDGE

Deborah Ball and colleagues are inspired by Shulman's work to develop Mathematical Knowledge for Teaching (MKT). As part of Subject Matter Knowledge, Hill and Ball (2009) consider Common Content Knowledge (CCK), a knowledge identical to that used in other professions in which mathematical knowledge is involved; Specialized Content Knowledge (SCK), a specific knowledge of teachers; and Horizon Content Knowledge (HCK), a kind of comprehensive view of mathematics teaching. As part of Pedagogical Content Knowledge (PCK), they consider the Knowledge of Content and Students (KCS), which combines knowledge of students and of mathematics; the Knowledge of Content and Teaching (KCT), which articulates knowledge about mathematics and about teaching; and the Knowledge of Curriculum (KC).

Recognition of the importance of knowledge of technology leads Mishra and Koehler (2006) to argue that the articulation of this knowledge with the others is fundamental. They then propose a model that is inspired by previous works and which not only includes the three basic domains of knowledge (knowledge of Content, Pedagogy and Technology), but also attends to the connections, interactions and constraints that are established between them. They consider Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and PCK. These three areas of knowledge are the essence of this model, called TPACK, and what truly distinguishes it from others previously proposed.

METHODOLOGY

This study assumed a mixed methodology, collecting the perceptions of 129 teachers through a questionnaire (quantitative section) and of four teachers through interviews (qualitative section). The questionnaire included 19 items related to the use of technology to teach Functions. The response options were five and ranged from *I totally disagree* (coded by 1) to *I fully Agree* (coded by 5). The sample was defined by the convenience method (Hill & Hill, 2012), and the questionnaires were distributed in several schools by teachers known to the authors. The sample consisted of 129 teachers, 64 from lower secondary and 65 from upper secondary. The semi-structured interviews were carried out with two teachers from the lower secondary (T1 and T2) and two teachers from upper secondary (T3 and T4) with a professional experience between 23 and 28 years. The interviews were based on the questions of the questionnaire and include the following dimensions: knowledge of technology, technology use, consequences of technology use, technology versus paper and pencil, skill development, and technology and assessment. In the analysis of the questionnaire, we began by determining the mean values of the codifications in each item. Later, the T-Test for independent samples was applied in order to compare the means of the two groups defined (teachers of lower and upper secondary), emphasizing the items in which there were statistically significant differences between the groups. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), IBM SPSS Statistics 23 version for Windows, and in the decision about the existence of statistically significant differences, the significance level of 0.1 was considered appropriate for an exploratory study, such as the one reported here. In the analysis of the interviews (in the part presented here), we use as the main criteria the identification of answers that could offer justifications for the answers obtained in the questionnaire.

RESULTS

An analysis of the questionnaire allows characterizing teachers' perceptions regarding the dimensions considered. It also allows identifying statistically significant differences in five of the items considered (Table 1). The interviews with the teachers clarify some aspects that might promote a better understanding of the answers to the questionnaire.

		Lower Sec (n=64)		Upper Sec (n=65)		value
	Items	$\bar{x}$	s	$\bar{x}$	s	p
Knowledge of tec	I feel comfortable using a graphing calculator to teach functions.	3,56	1,332	4,55	0,685	0,000**
	I feel comfortable using specific software to teach functions.	3,47	1,154	3,74	0,889	
Technology use	Technology helps to do transformations on graphs of functions.	4,25	0,943	4,49	0,590	0,082*
	Technology is mainly useful for drawing graphs of functions.	3,06	1,125	3,29	1,057	

	Technology allows establishing relations between the different representations of functions (algebraic-graphical-tabular).	4,36	0,698	4,28	0,696	
	Technology should be used mainly to introduce concepts of functions.	3,25	0,891	3,15	1,049	
Consequences of technology use	The use of technology favors a teaching of Functions less expositive and more participative.	4,25	0,667	4,18	0,808	
	The use of technology makes the teacher look for tasks about Functions in other sources besides the textbook.	3,72	1,031	3,43	1,131	
	The use of technology frees the teacher and the students from routine activities.	3,55	1,022	3,40	1,028	
Technology versus paper and pencil	The resolution of tasks on Functions must be done with paper and pencil and checked with technology.	3,89	0,799	3,49	1,033	0,016**
	The resolution of tasks on Functions must be done with technology and checked with paper and pencil.	3,37	1,120	3,54	0,937	
	When solving tasks on Functions one must resort to technology when it is impossible to solve using analytical processes.	4,03	1,038	4,25	0,867	
Skill development	The use of technology develops the visualization skill.	4,33	0,736	3,97	0,728	0,006**
	The use of technology challenges the student to think.	4,13	0,917	3,74	0,691	0,008**
	The use of technology develops skills relevant for symbolic manipulation.	3,44	0,957	3,28	0,976	
Technology and assessment	Students should be allowed to use the technology they used in class during assessment.	3,83	0,952	3,88	0,960	
	The use of technology leads the teacher to change assessment.	3,39	1,107	3,34	1,020	
	The use of technology in assessment leads the teacher to ask more questions of understanding and problem solving than memorization.	3,89	0,961	3,77	0,897	

Note: statistically significant differences for $^{*}p<0$ $^{**}p<0,05$.

Table 1: Synthesis of teachers' answers to the questionnaire

With regard to knowledge of technology, teachers express some confidence in their ability to use it. However, statistically significant differences were found between the two groups of teachers, with upper secondary teachers showing much more confidence in the use of the graphing calculator. One difference that the teachers interviewed recognize and assume as predictable.

When the use of the graphing calculator became compulsory in the upper secondary, the teachers were somehow forced to learn how to use it. Some teachers will be more

at ease than others, I mean, there are those who know how to program, but the basics everyone knows. In the lower secondary it isn't like that. (US, T3)

Regarding the use of technology in teaching, teachers consider it very appropriate to establish relationships between different representations and to perform transformations of function graphs. In the latter case, it is even possible to identify a statistically significant difference, and upper secondary teachers are the ones who most consider the use of technology as useful for performing function graphs transformations. Although less convincing, teachers still recognize the potential of technology to draw graphs and to introduce concepts.

Technology makes it easy for them to perceive the relationship between the graph and the expression, or between the graph and the table. It helps a lot. (...) It is not possible to deny it. Even those who don't like technology have to recognize it. (LS, T1)

Well, the transformations of graphs of functions are usually studied in the upper secondary, so I think it's to be expected that the teachers of the upper secondary are the ones who most refer to it. And technology is great for that... with paper and pencil it was basically us telling, with technology they can see it. It's completely different. (US, T4)

The active involvement of students in learning is what teachers, regardless of their teaching level, recognize as a consequence of the use of technology. Besides that, they consider that the integration of technology leads the teacher to look for tasks in places different than the textbook and they also consider that technology eases the teaching and learning of routine tasks.

When you use technology the tasks get a little bit different, it is not just exercises... and sometimes it isn't easy to find those kind of tasks in a textbook... but I think this is changing. More and more technology is a reality in the classroom and the textbooks are beginning to take this into account. In the upper secondary all the textbooks have tasks where the use of the graphing calculator is required. (LS, T1)

Teachers in both groups, lower and upper secondary, agree with the use of technology when a resolution is not possible by analytical procedures. However, agreement is no longer so strong as to whether technology should be used before or after using paper and pencil methods, although teachers in both groups take a favorable view in both cases. Still, it is the lower secondary teachers who are more in favor of a paper and pencil approach and the use of technology only after this, and this is a statistically significant difference. In what concerns a use of technology followed by a paper and pencil approach, it is the upper secondary teachers who are most in favor of it.

I think this is the big problem... and it will get worse with the new generations that are increasingly technological generations. What can you do with technology and what do you have to do without it? Tradition has a very strong impact in school. And teachers are still from a generation where knowledge is what you do by yourself. And the curriculum is like this, isn't it? It was developed by people of our generation. (LS, T2)

I see technology as something that helps you understand and so you use technology to improve understanding and to learn how to do it without technology. If you use technology just to do it, then afterwards how do you convince students to do it without technology? And if you already know how to do it without technology, what is the point in using technology? Only if you intend to be faster. (US, T4)

Technology is viewed by teachers as including the potential for developing visualization skills and encouraging students to think, and it is the teachers of the lower secondary who most recognize these potentialities, doing so in a statistically significant way. Regarding the potential of technology to develop the capacity for symbolic manipulation, teachers assume a more neutral, yet positive, position.

It always depends on how you use it, but I think technology always allows you to focus on understanding and not so much on mechanization. And I think this is important at all levels. In the upper secondary because you begin to have some more elaborate concepts and it can help to achieve a deeper understanding. In the lower secondary the concepts are not so complex, but the students are also younger and it can equally help them to realize meaning. (US, T3)

For assessment, teachers believe that students should be able to use the technology just as in class. This option, however, has an impact on the questions posed to the students, and it is teachers' opinion that this leads them to formulate more questions focused on understanding and problem solving than on memorization. There is also the idea that the use of technology may lead to changes in the forms of assessment.

In my opinion, the use of technology in exams allows posing different types of questions and allows reducing the weight of calculations, since it becomes possible, for example, to adopt a graphical resolution. But in fact I don't think we have had these big changes. There was a lot of talk about it when the graphing calculators came along, but it didn't change that much. (US, T4)

CONCLUSION

Knowledge of technology does not appear to be in any way identified by teachers as an obstacle to their use of technology. Even so, upper secondary teachers feel more comfortable with the graphing calculator, a situation that can result from the fact that the curriculum has made its use mandatory for about 20 years.

Teachers understand that technology is particularly suited to work with function graph transformations and to establish relationships between representations. This is a circumstance that expresses the teachers' knowledge about how technology can bring new approaches to mathematics, but also about the contribution that work with different representations can bring to the understanding of Mathematics, in line with Burril's (2008) ideas. And the potential of technology for the study of transformations of graphs of functions is significantly more valued by upper secondary teachers. This is an aspect that can be expected, even for the teachers themselves, if we take into account that it is at this level of education that this type of content is most worked.

Teachers in both lower and upper secondary agree that the use of technology favors a less expositive and a more interactive teaching approach - something that reflects the teachers' knowledge regarding the way technology allows the adoption of new forms of teaching (Niess et al., 2009). The place where the teachers look for tasks for their students is however a little different in the two levels of teaching. The teachers of lower secondary look for tasks in sources other than the textbook, which is not the case of upper secondary teacher. This choice might be related to the mandatory use of graphing calculators at upper secondary, a situation that might have caused an increase on the quantity of tasks on textbooks requiring this technology.

The teachers agree to the use of technology when analytical approaches are not available. In the other cases, they agree with its use to check paper and pencil approaches (this trend being significantly stronger for lower secondary teachers). However, the lower secondary teachers are less supportive of using a paper and pencil approach to check a solution achieved using technology. This articulation between technology and paper and pencil seems to be a delicate aspect of technology integration, with the teachers interviewed hesitant to take a position. This suggests that the knowledge of how to teach with technology still lacks some development in order to achieve a full integration of technology, as advanced by Niess et al. (2009).

The use of technology by the students promotes the development of visualization skills and challenges the students to think (Rocha, 2016). This is a significantly stronger perspective among the teachers of the lower secondary. This may be related to the less formal reasoning of the younger students and to the associated intention of the teachers to present some more intuitive approaches. It is still another indication of the teachers' knowledge regarding the contributions that technology can bring to student learning.

The teachers agree with the students' use of technology in the tests, since this allows teachers to put more questions requiring understanding instead of memorization. This focus on conceptual rather on procedural understanding is a consequence of technology use on assessment, as pointed by Niess et al. (2009). However, the teachers interviewed consider that in practice the changes are smaller than what may be expected. The teachers' perspectives about technology use in assessment are however less convincing, suggesting that this is another field where technology integration has not yet been fully achieved.

Overall, teachers seem to have professional knowledge regarding the integration of technology in mathematics teaching. The knowledge of technology seems to be considered adequate by the teachers - that is, the teachers do not seem to feel gaps at the level of their TK, according to the TPACK model. References to the potential of technology related to Mathematics (eg work with different representations) and its teaching (eg adopting methodologies where the students take a more active role) are identified - ie TCK and TPK, according to the TPACK model. But circumstances are also identifiable where the integration of technology is not complete (for example, with regard to assessment and to articulation between paper and pencil and technological approaches), suggesting that teachers' knowledge could still be deepened - or that their

TPACK could be developed. According to Niess et al. (2009) development TPACK model, teachers *recognize* and *accept* the use of technology in assessment and in the teaching and learning process but they are still *adapting* to it. Some development is needed in order to achieve the *exploring* and *advancing* levels, where the teachers engage students at high-level thinking activities, exploring various instructional strategies and assuming technology fully as a teaching and learning tool.

It would be interesting to deepen research into precisely the reasons why teachers who seem to have a good knowledge of technology and its potential for learning mathematics find it difficult to take a position on the articulation between the use of paper-and-pencil and technology and also relatively to the impact of technology on assessment.

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