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# Teach Mathematics with technology: put into practice a theoretical framework

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**Abstract:** This paper is a report on the findings of a study conducted to examine the results of implementing an educational technology course focused on interactive whiteboard classroom applications according to TPACK Mathematics. It was examined the change in teachers' attitudes toward using technology and perceived ability to integrate interactive whiteboards in Mathematics class, 9 months after and 3 years later. It is exposed the theoretical TPACK about integration of educational technology in the teaching/learning process, reflecting on the need for teachers to have continuous professional development. It was observed a positive evolution about their use of ICT in classroom context and their level of competence in ICT use, reporting that this kind of training is usefulness in their teaching practice and can contribute to improve student learning by their professional development.

**Kew-words:** Professional development, TPACK, Mathematics, Educational technology.

## Introduction

Teaching with technology is not an easy task! Several investigations have been carried out on the technology integration in the teaching/learning process and repeatedly concluded that the methodologies used should be rethought, not occurring improvements in educational attainment, teachers were not comfortable with the use of these technologies and there was a great lack of resources in schools (Culp, Honey & Mandinach, 2003).

How far it makes sense to say that the use of educational technology improves students achievement in Mathematics? Through various policies developed over the past twenty-seven years, the Portuguese schools have been equipped with technological equipment, facilitating access to Internet, availability of laptops, handling software, easy viewing of resources for the numerous existing video projectors in classrooms, interactivity and motivation promoted by interactive whiteboards, teacher training in digital skills ... However, has really occurred a change of paradigm? Teachers are able to use information and communication technologies (ICT) effectively? It is therefore essential to reflect on how ICT should be integrated in classroom context, differing from discipline to discipline, from content to content, according to their own objectives, taking into account the context in which the school and classroom teacher are inserted.

In this paper we present the theoretical TPACK about integration of educational technology in the teaching/learning process, reflecting on the need for teachers to have continuous professional development, which should be based on the content, not in the technology itself, depicting the diversity of learning activities based on the content, to present a theoretical framework for the integration of technology in Mathematics. "Professional development programs are systematic efforts to bring about change in the classroom practices of teachers, in their attitudes and beliefs, and in the learning outcomes of students" (Guskey, 2002, p. 381). The purpose of this study was to examine the results of implementing an educational technology course focused on interactive whiteboard classroom applications. It was examined the change in teachers' attitudes toward using technology, beliefs in the value of using technology in the classroom and perceived ability to integrate interactive whiteboards in Mathematics class.

## Professional development

Despite many efforts made towards the use of technology in teaching, it is still safe to say that the majority of teachers are unaware on how to do it correctly. It is then a challenge to prepare teachers in order for them to use technology more often and in a more effective way.

If the technology based activities prepared for lessons are not carefully thought for specific topics and objectives and instead are used without a real purpose and not in context, then we are clearly in the presence of a wrong and shallow use of technology in education. Ferdig (2006, p. 752) states that "a good innovation is consequently defined in relationship to what it is as well as how it is implemented". This opinion is also shared by

Mishra & Koehler (2006, p. 1033) when they say that “merely knowing how to use technology is not the same as knowing how to teach with it”.

There are three important criteria to determine the performance of any innovation (Ferdig, 2006, p. 754-756): i) appropriate use of technology (despite the influence of the teacher in the way he/she implements a specific type of technology, it is also important to remember that there are better moments than other to do that); ii) use of cognitive tools in order to assess the effectiveness of specific technologies (it is not unusual to find situations where technology is used in lessons without any relevant connection with the topic being studied not to mention the lack of specific objectives for its use); iii) use of different methods for a more complete analysis (the success of technological innovations should be assessed according with rigorous criteria established by teachers).

Teachers usually consider themselves not to be well prepared to introduce the ICT in their lessons. This assumption is based in their poor levels of experience in these matters as well as the incorrect use given to some technological innovations available, hence justifying the need for appropriate formation in this area. This should link all three components (pedagogy, technology and contents) and keeping in mind the development of the TPACK and therefore create a significant change in the way teachers prepare their lessons. Taking in consideration a more collaborative process of development of teachers, based in the idea “learn how to learn”, Koehler & Mishra (2005, p. 135) consider knowledge to be built upon specific objectives and specific concepts and it’s influenced by the interactions that take place and hence straighten the bonds between pedagogy, technology and content.

According with Cox (2008), teachers will be able to take good decisions related with the integration of ICT in lessons only when they can handle the use of it in a context of the curricular programs being used and also when using correct strategies to implement that. But will teachers in fact acquire some kind of operational comprehension of the complexity of relations that exist between content, pedagogy and technology?

Harris, Mishra e Koehler (2007, p. 11) highlight the fact that learning new skills related with technology is not enough to develop an effective understanding of its use in lessons. They state that learning about a certain technology is not the same as learning about what to do with it in a perspective of education. Harris e Hofer (2006) add that for a better understanding of the TPACK, and taking in consideration the several different specifications of each subject, we should start by getting in touch with learning activities based in content and then deciding which ones should be selected and combined with other. There are several resources that can’t be separated from its content nor from the dominant activity which is attached to it and this is why the activities related with the TPACK should always be presented according with the specifications of each subject and not so much with the technology that each brings incorporated.

## **Mathematics’ TPACK**

The Mathematics teacher, to have success, needs a deep understanding of Mathematics (content), of teaching/learning process (pedagogy) and of technology, in an integrated way, so that when planning lessons, “as teachers think about particular Mathematics concepts, they are concurrently considering how they might teach the important ideas embodied in the mathematical concepts in such a way that the technology places the concept in a form understandable by their students” (Niess, 2006). However, teachers, in general, have a limited knowledge about educational technology and its application in the Mathematics teaching/learning process, reinforcing the idea of the need for a teacher continuous training to integrate technology education according to TPACK’s framework.

Niess et al (2009, p. 18-19) presented a theoretical integration of TPACK in Mathematics teaching/learning, "Mathematics TPACK", organized, with similarity to that proposed by AMTE Technology Committee (2009), in around four areas:

- 1- Designing and developing digital-age learning environments and experiences – Teachers design and develop authentic learning environments and experiences incorporating appropriate digital-age tools and resources to maximize mathematical learning in context.
- 2- Teaching, learning and the Mathematics curriculum – Teachers implement curriculum plans that include methods and strategies for applying appropriate technologies to maximize student learning and creativity in Mathematics.
- 3- Assessment and evaluation – Teachers apply technology to facilitate a variety of effective assessment and evaluation strategies.
- 4- Productivity and professional practice – Teachers use technology to enhance their productivity and professional practice.

From this framework are set goals for the technology integration in Mathematics, but how is realized the development progression of Mathematics TPACK? Niess et al (2009, p. 9) proposed a model that shows the

Mathematics TPACK progression according to technology integration in Mathematics held by teachers, inspired by the model of innovation decision process introduced by Rogers (2003). Thus, teachers need to go through a five-step process to address the final decision to accept or reject a particular innovation for teaching Mathematics with technology:

1. *Recognizing* (knowledge), where teachers are able to use the technology and recognize the alignment of the technology with Mathematics content yet do not integrate the technology in teaching and learning of Mathematics.
2. *Accepting* (persuasion), where teachers form a favourable or unfavourable attitude toward teaching and learning Mathematics with an appropriate technology.
3. *Adapting* (decision), where teachers engage in activities that lead to a choice to adopt or reject teaching and learning Mathematics with an appropriate technology.
4. *Exploring* (implementation), where teachers actively integrate teaching and learning of Mathematics with an appropriate technology.
5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning Mathematics with an appropriate technology.

AMTE's Technology Committee created a visual description (figure 1) for this theoretical framework, emphasizing the non-linearity of the process, this is, the no regularity progression at the transition from one level to another. Different experiments may lead to a level's lowering or conversely the acceptance of a new technology. A teacher can achieve different levels for different aspects of its activity.

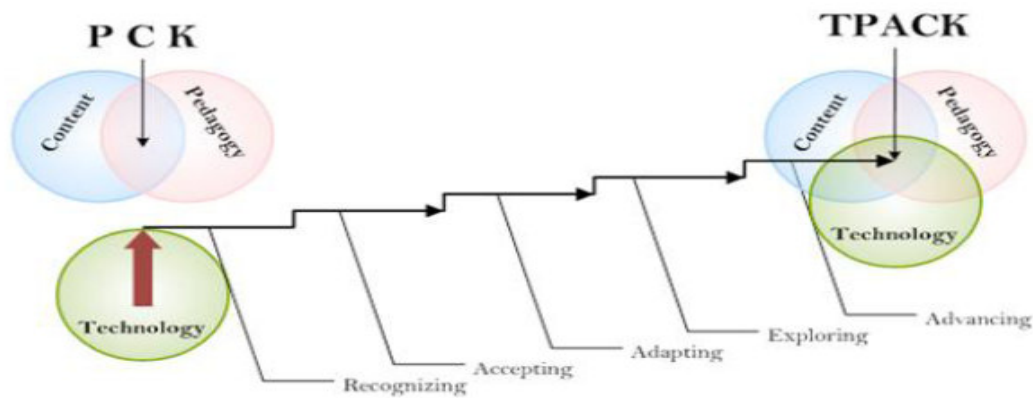


Figure 1: TPACK's development (Niess et al, 2009, p. 10).

Given that this interpretation of TPACK's development is not directly related to Mathematics, the AMTE's Technology Committee decided to create a model of teacher's TPACK Mathematics development, developing a set of descriptors according to four major themes: curriculum and assessment, learning, teaching, access. In summary, it was developed a model of educational technology integration in Mathematics teaching/learning process, which unfolds in five stages: recognition, acceptance, adaptation, exploration and advancement, according to four major themes: curriculum and assessment, learning, teaching, access.

## Findings

In a context of professional development, 20 Mathematics teachers attended a 50 hours' workshop, during 3 months, about ICT, specific about the integration of interactive whiteboards into their subject. They presented very different teaching experiences: half of the teachers worked for less than 10 years, 35% between 10 and 20 years and 15% worked for more than 20 years with students, half have a firm job while the youngest (less than 10 years working) still signs a new contract every year. They answered a questioner, on-line, when they attended the workshop, 9 months later and 3 years after the training, so that we could understand a little about the evolution of their opinion and action of ICT.

Through the analysis of figure 3, it can be seen that 75% of this teachers often use ICT in the classroom, being able to observe an evolution. Professional development must be seen as a process, not as an event (Loucks-

Horsley et al., 1998). During the time it is easy to observe there is a change into their practice. If there were 35% of teachers that rarely made use of ICT in their classes, which increased to 45% after 9 months, now only 25% still aren't able to integrate ICT into Mathematics lessons. Some refereed that school resource conditions are not equal and when they change school, especially the ones that sign contracts every year, some resource conditions of the new school don't allow them to use ICT always. No teacher now feels that their level of competence in ICT use is bad or very bad, 85% had even considered having a good or very good level of competence in using the ICT in their teaching, taking place an increase in self-esteem of teachers towards the use of educational technologies. According to Niess (2005, p. 511), teachers training, usually focus only on technological knowledge, forgetting pedagogical issues, but this workshop was built under TPACK's framework, regarding the specificity of the subject (Mathematics), pedagogical and technological concerns and the context of each teacher.

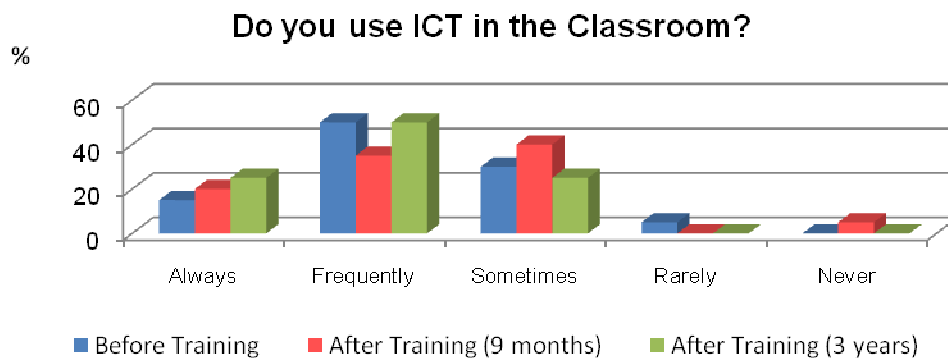


Figure 3: ICT use by teachers in the classroom before and after training.

Specific, about the use of interactive whiteboards in the classroom context (figure 4), there is a small increase, comparing with the results from Sampaio e Coutinho (2011, p. 148). Teachers are reluctant to adopt new practices unless they feel certain they can make them work (Lortie, 1975). Now, 40% usually use this educational tool to promote students learning and 35% use it moderately, having pointed that there are still many classrooms that are not equipped with interactive whiteboards. However, some teachers stated that they use more ICT, in global, because the workshop they attended helped them to create more interactive classes and to develop Mathematics TPACK, facilitating Mathematics instruction with technology as an integrated tool. “The experience of successful implementation ... changes teachers’ attitudes and beliefs. They believe it works because they have seen it work, and that experience shapes their attitudes and beliefs” (Guskey, 2002, p. 383). Teachers reported as main advantages for using interactive whiteboards: student’s motivation, reuse the same materials, possibility to create interactive materials, making the most of class time, access to new tools and exchange ideas with colleagues. They also reported some disadvantages: expensive equipment, not all classrooms have it and it takes a lot of time to prepare materials. “Learning to be proficient at something new and finding meaning in a new way of doing things requires both time and effort” (Guskey, 2002, p. 386).

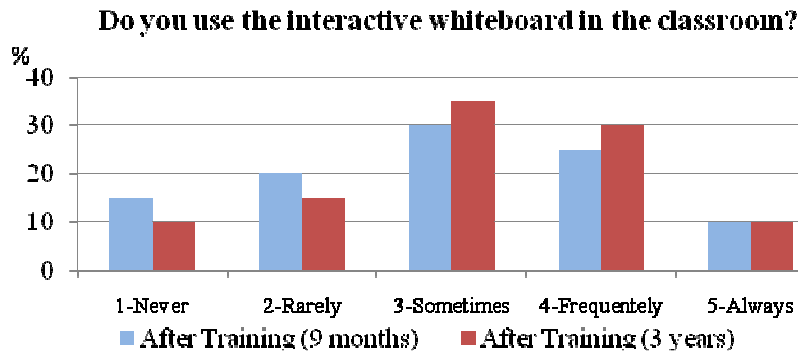


Figure 4: Use of IWB by teachers in the classroom after training.

Finally, teachers were asked about the degree of usefulness of training in their teaching practice, 9 months after (Sampaio & Coutinho, 2011, p. 149) and 3 years after, being obtained exactly the same results, an average of

4.1 on a scale from 1 (nothing useful) to 5 (very useful). Nobody found anything useless and 75% found it useful or very useful. About the possible contribution of training to improve student learning, also on a scale from 1 (nothing) to 5 (completely), we obtained an average of 3.75, and 60% considered that the training contributed greatly to that improvement, 35% considered that it makes no difference and 5% that as not contributed a lot. Regarding students improvement, there is a small increase about teachers belief after 3 years of the training, because they use ICT more frequently and “teachers need time to develop their technological fluency, apply pedagogic principles to the available materials or to the development of materials, and then to incorporate the IAW seamlessly into their teaching” (Miller, Glover & Averis, 2005, p. 16).

## Conclusions

The impact of educational technology varies greatly, since the quality of ICT use is not directly related to the technology itself, but with how this technology is applied by the teacher in classroom’s context, after a careful selection of learning activities that fit with specific objectives and content. Several projects have been undertaken to equip the Portuguese public schools like cheap computers for students and teachers, broadband access to the Internet, liberalization of educational software, greatly improving access to ICT for all. However, most of these projects were based only on providing technologies, ignoring the professional development of teachers. Thus, this provision of technological tools brought no big impact on the educational success of our schools. It is urgent to work with teachers so that they can teach its subjects with ICT. But how to help teachers integrate efficiently technology into their lessons? The answer to this question is quite complex, the TPACK emerging as a theoretical framework that intends to position itself as a possible explanation, focusing not on the pedagogy, technology or content itself but in the interaction of these three components set.

When a carpenter considering building a table, first formulates a plan of construction, such as a drawing the table, for example, after selects the materials he will need and finally will choose only the tools needed to accomplish this construction. Does a carpenter ever ask: with this tool what can I build? Well, in the case of education, we face the opposite! How often, for example, a teacher wants to use a spread sheet and only after builds a lesson plan for content whatsoever. We shouldn’t first select the tool; instead, we must carefully choose the content and educational objectives to prepare a lesson plan, choosing the most appropriate methodology and then set up the necessary resources and ICT.

The technology integration in teaching has influence the way we teach, but also in what we teach. The technology itself does not present an added value; it’s needed to establish strong connections with pedagogy and content itself. It’s needed a flexible knowledge to fit different subjects of the curriculum with the pedagogy that will be used and the technology that will assist this learning, respecting always the context in which it is inserted. It interferes with the teaching/learning process: technologies available, lesson’s duration, students' prior knowledge, physical space available, students and teachers attitude, teacher's own knowledge, interpersonal dynamics that are established, class’s cultural diversity, students socio-economic conditions ...

Being a Mathematics teacher is an arduous task that requires constant updating of content itself, the pedagogical knowledge to be applied in classroom context and technological knowledge, which are always changing. Through the reformulation of Portuguese Mathematics curriculum programs, students must learn to handle a set of technological tools and instruments, which will be assisted by the teacher. Thus, the technology is imposed to teachers, but how to use efficiently educational technology in Mathematics? Mishra and Koehler (2006) believe that teaching is a highly complex activity that uses various types of knowledge: pedagogical, technological and content, that relates to each other, proposing a theoretical integration of technology in the teaching/learning process, TPACK. Harris, Mishra and Koehler (2009) add that teachers can learn to identify, differentiate, discuss, choose, combine and use learning activities based on curriculum, according to TPACK, if they organize their classes around the content and they developed some taxonomies of learning activities based on the content. In particular, in the case of Mathematics, Grandgenett, Harris and Hofer (2011) found seven types of activities: consider, practice, interpret, produce, apply, evaluate and create. About the technology integration in the Mathematics teaching/learning process, it was developed TPACK Mathematics that takes place in five stages: recognition, acceptance, adaptation, exploration and advancement, according to four major themes: curriculum and assessment, learning, teaching and access.

Continuous professional development is a way for teachers to develop TPACK Mathematics and share educational resources and experiences with each other’s. Since the recognition that technology may or may not be useful in Mathematics to the effective classroom integration and their evaluation, there is a long way to go. It was applied a workshop about interactive whiteboards integration in Mathematics to 20 teachers and it was conducted a study to perceive their attitudes after 3 years. It was observed a positive evolution about their use of ICT in classroom context, their level of competence in ICT use, an increase in self-esteem towards the use of educational

technologies, reporting that this kind of training is usefulness in their teaching practice and can contribute to improve student learning by their professional development.

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