TECHNOLOGY AS A RESOURCE TO PROMOTE MATHEMATICS TEACHING

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*This work is supported by national funds through FCT - Foundation for Science and Technology, I. P., in the context of the project PTDC/CED-EDG/32422/2017

This paper aims to show how a range of technologies may be used as a resource to promote mathematics teaching. This study occurred in the framework of a STEM Continuing Professional Development Programme targeted to in-service primary school teachers. In this study we use a qualitative methodology and an interpretative approach by means of a case study. We conclude that technological resources enable the development of mathematical tasks appropriate for the primary school syllabus, that motivate students to learn this subject matter.

Keywords: Technology, mathematics, hands-on, mobile technologies, primary school.

INTRODUCTION

The importance of developing research on technology in mathematics teaching and learning is recognized by the mathematics education community. This is evident since the first Congress of European Research in Mathematics Education (CERME) in 1999, that included a Thematic Working Group (TWG) on technology among the seven proposed themes (Trgalová, Clark-Wilson, Weigand, 2018). The same authors conclude their reflection by referring the need to focus on emerging technologies in future European Researchers in Mathematics Education (ERME) congresses.

Advances in technology have the potential to enhance the implementation of integrative approaches related to STEM (Science, Technology, Engineering and Mathematics) by highlighting mathematics (Stohlmann, 2018). This author states that, although there is evidence of the potential of this approach, “there is a need for additional curriculum development and research on the effectiveness of various approaches” (p. 3)

This research is situated within a broader STEAMH (Science, Technology, Engineering, Arts, Mathematics and Heritage) project in Portugal, which began in 2013 and is coordinated by the first author of this paper (Costa & Domingos, 2018). Since 2015, in collaboration with a training centre and elementary schools, the project promotes in-service primary school teachers’ professional development. The team members are university teachers who design hands-on experiments and prototypes to promote STEAMH learning. Examples are “Sonicpaper” (Ferreira, Neves, Costa, & Teramo, 2017) and “SolarSystemGO” (Costa, Patrício, Carrança, & Farropo, 2018).

The focus of this study is to discuss technologies, namely videos, internet and mobile technologies, as a resource to design mathematical tasks related to the topic of sound. In this regard, our research question is: How may technologies be used as a resource to promote mathematics teaching related to the context of sound? We answer this question by presenting an empirical study that occurred in the framework of a STEM Continuing Professional Development Programme (CPDP) targeted to primary school teachers. In particular, we present a case study of a teacher who participated in the CPDP for two school years and used technology to design and implement mathematical tasks related to sound.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The great lack of professionals in STEM subjects must be countered with an early intervention at the first grades of primary school (DeJarnette, 2012; Rocard et al, 2007). In this regard, it is recommended the incorporation of hands-on experiments in class, since it leads to significant improvements in performance and produce positive attitudes towards science (Mody, 2015; Johnston, 2005).

Kim e Bolger (2017) support the integration of STEM by involving teachers into interdisciplinarity lessons adequate to this approach. Kermani and Aldemir (2015) defend STEM integration in the first years of school, through teachers' professional development, being necessary to design resources to implement hands-on experimental activities.

STEM education can be both a form of innovation for teaching mathematics (Fitzallen, 2015) and can increase mathematical performance (Stohlmann, 2018). Also, technology has potential to integrate mathematics and to promote students' motivation and meaningful learning (Costley, 2014). In fact, technology resources, in particular mobile technologies, are efficient to catch children's attention and can engage students to learn mathematics and science, according to primary school syllabus (Costa & Domingos, 2017).

According to Pepin (2016) "A resource can be of material (e.g. texts) or human (e.g. colleagues) nature" (p.11). In particular, resources can be science and mathematical tasks, or the work developed by academics, to be used in the classroom or in sessions to promote teachers' professional development (PRIMAS, 2010). Resources are crucial for teachers who shape them according to their idiosyncrasies, preferences and personality during the process of their interpretation and design (Pepin, Gueudet, & Trouche, 2013). Tasks are teaching and learning activities, carried out in school environments, being inserted in the curriculum in action (Gimeno, 2000). But, according to Ball (2003), "No curriculum teaches by itself and content does not act independently of the interpretation of the professionals who convey it" (p. 1). In fact, it is the teacher's job to analyse curriculum contents in order to stimulate the students to learn them (Gimeno, 2000). In this regard, the teacher becomes "an active agent in curricular development, a modeler of the transmitted contents (…) conditioning the way students learn" (Gimeno, 2000, p166). This leads to the need of thinking and designing adequate teachers' Professional Development models and to select the contents for the Professional Development Program (PDP) (Gimeno, 2000, p166). A PDP will only be successful if teachers can apply in their classrooms what they learned and experienced during training (Buczynski & Hansen, 2010); and only achieve real effects if innovation is appropriated by the teachers and transformed into their own practice (Zehetmeier, Andreitz, Erlacher, & Rauch, 2015).

METHODOLOGY

In this research, we use a qualitative methodology and an interpretative approach by means of a case study. According to Yin (2005), a case study is an empirical investigation that looks at a contemporary phenomenon within its real-life context, allowing a generalization of the obtained results. Data collection includes participant observation (first author of the paper is a participant observer) and portfolios compiled by the teachers (Cohen, Lawrence, & Keith, 2007). Participant observation takes place in the workshops with the teachers (to learn and practise what they are expected to implement) and in their classrooms (to observe them in action). During participant observation notes and photos are taken for future analysis. Also, document analysis is performed on the teachers' portfolios (presented by the end of each school year), alongside their critical account of their CPDP and their proposals and implementation of innovative practices.

In the CPDP, teachers choose a science theme to develop in the classroom with their students. In this paper, we selected a teacher who used technology to develop several mathematical tasks related to sound. Teacher Marina (fictitious name) started the CPDP at 48 years old with 27 years of service and she was responsible for a 2nd grade class with 16 students. She developed STEM tasks related to sound in the school years 2016/2017 and 2017/2018. At the workshops of the CPDP, she learned about sound and how to perform STEM hands on experiments. These workshops were conducted by electrical engineering lecturers who designed prototypes to reproduce and measure the sound, amongst other tasks. They also used internet resources to provide the teachers with tools that they could use with their students such as videos and free software. An example is the Sound Meter application that allows sound intensity measurements (in decibels) and can be used on smartphones.

DATA ANALYSIS AND DISCUSSION

In this section, we begin by analysing the case study of teacher Marina to show her development of mathematical tasks with technology resources. The following information, namely tables and pictures result from participant observation and the teacher's portfolio.

Marina's case study

In class, with her students, Marina started by introducing sound by inquiry. In this regard, questions such as "What is sound?" were asked of her students. The teacher wanted them to reflect on this subject and to discuss possible answers. She also asked the students to make draws related to sound in order to understand better their perceptions about sound (Figure 1).

Figure 1. Students' perceptions about sound

After this discussion, Marina encouraged her students to find more information about sound using Wikipedia. She also showed videos related to this subject to engage the students to learn about the sound properties. After debate, students built a prototype to "visualize" sound (similar to the prototype teachers learned about during the sound workshop) and simulated "wave propagation" (Figures 2 and 3).

Figure 2. **Prototype to "visualize" the sound of human voice**

With the purpose of exploring mathematics, several sound measurements were taken, such as frequency (measured in hertz) and intensity (measured in decibels). For example, with the Sound Meter application in a mobile phone (Figure 3), the teachers asked each student to measure and record the intensity (in decibels) of several sounds in a table (Table 1).

Figure 3. Wave propagation and sound intensity measurement

Action / Decibels	Whisper	Speak	Laugh	Cry	Scream	Sing	Clap hands
40	X						
50							
60		X					
70							X
80			X	X	X	X	

Table 1. Each student registered the intensity of their sound in decibels

After each student had collected their data, they shared it with the whole class. Next, with the help of the teacher, another table with the information from the whole class students was built (Table 2).

	30	40	50	60	70	80	90
Whisper	0	12	4	0	0	0	0
Speak	0	0	0	4	9	3	0
Laugh	0	0	0	0	0	16	0
Cry	0	0	3	13	0	0	0
Scream	0	0	0	3	8	5	0
Sing	0	0	0	4	8	4	0
Clap hands	0	0	0	0	16	0	0

Table 2. Intensity measurements of the sound in decibels of all the students

With the collected data, several tables were built to promote the organization and processing of the data obtained from the measurement results (Figure 4), in accordance with the mathematics' syllabus.

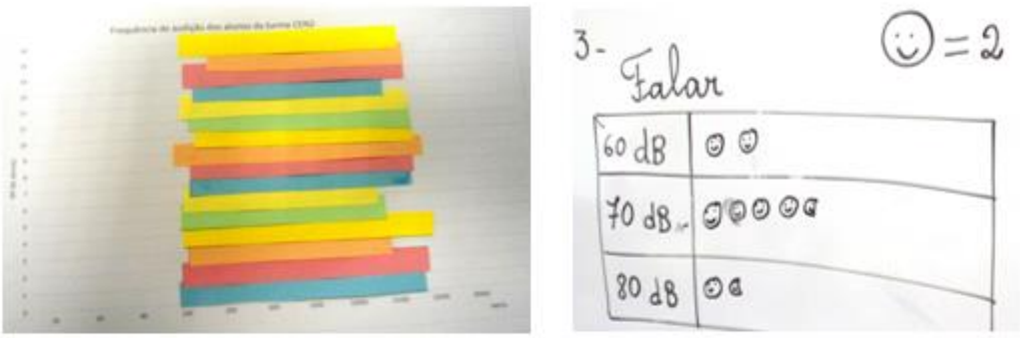

Figure 4. Organization and processing of data obtained from sound measurements

In figure 4, the first picture shows a graphic where the frequencies (in hertz) are represented on the horizontal axis and the students' names on the vertical axis. Each colourful rectangle represents the amplitude of the sound frequencies measured by each student. The second image is a pictogram, where each "face" represents two students who recorded the corresponding sound intensity measurement (in decibels) while they were talking.

In the 2017/2018 school year, Marina decided to conduct more tasks related to sound. She asked the students to look at the technical labels of home appliances to investigate the noise that they produce and bring the collected information to share with their peers. In class, all of the information was organized by the students with the teachers' supervision (Table 3).

HOME APPLIANCE	MODEL	NOISE LEVEL
Clothes dryer	Indesit IS41V	66 dB
	Orima	69 dB
	Indesit IDV75	69 dB
Refrigerator-freezer	Bosh	41 dB
	Candy	43 dB
	LG	37 dB
Washing machine	AEG	39 dB
	Balay	50 dB
	Candy	43 dB
Vacuum cleaner	AEG	76 dB
	Balay	64 dB
	Siemens	81 dB
Extractor hood	Candy – CBT6240X	64 dB
	Candy – CBG 640X	67 dB
	Meireles	65 dB
Refrigerator	Hotpoint/Ariston	35 dB
	Indesit	45 dB
	Samsung	41 dB

Table 3. Noise level of some home appliances according to the respective model

The teacher used this collected information to create worksheets for the students to solve several problems and exercises. Marina used technology to develop exploratory and investigative mathematical tasks. The technology resources included computer, smartphone, internet, video, Wikipedia and software such as the Sound Meter application. Mathematical tasks included problems and exercises mainly related to organization and processing data. Figure 5 gives an example of the work developed with the students.

In her final report, Marina argues that "it's possible to implement a transversal approach of contents, relating mathematics to science and technology". Regarding her students, she verifies that they "motivate and engage much more easily in these types of tasks". Below follows an excerpt of the reflections made by the teacher in her final report:

(…) the training action has contributed to the acquisition of new knowledge that will allow me to improve my professional performance and to have a positive impact in class, providing the students with diversified experiences of learning and development of scientific skills. (Marina's final report, June 2017)

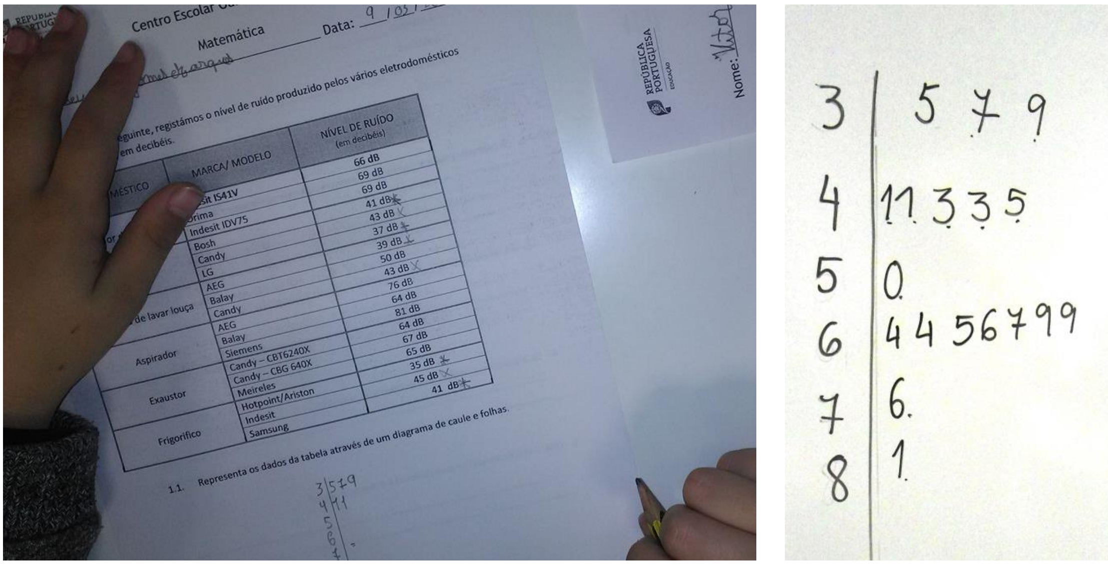

Figure 5. **Representation of the data from the table through a stem-and-leaf diagram**

Marina's perceptions show that participating in the CPDP was a positive experience that impacted her knowledge and practices. She also recognized impact on her students and that these practices promoted their interest to learn the subject matters. In summary, Marina used technology resources to design and implement mathematical interdisciplinary tasks related to sound and recognized that this kind of approach promoted the interest of her students to learn other subject matter such as mathematics. As exemplified above, mathematical tasks proposed by the teacher and performed by the students included problems and exercises related to several topics of the Portuguese curriculum such as "Numbers and Operations" and "Data Organisation and Processing", including tables, graphics and diagrams

FINAL CONSIDERATIONS AND CONCLUSIONS

This paper aims to contribute to existing literature by presenting an empirical study about the development of mathematical tasks using technological resources. In this regard, we presented a case study of a teacher who participated in a CPDP for two school years. In the context of her participation in the CPDP, she designed and implemented interdisciplinary tasks in her class. Indeed, teacher Marina designed and developed several mathematical tasks using appropriate technology, becoming "an active agent in curricular development" (Gimeno, 2000, p166).

Marina's example shows the development of exploratory and investigative mathematical tasks using technological resources such as computer, smartphone or the Sound Meter application. It appears that the CPDP was successful in that Marina applied in her class her learnings from her training (Buczynski & Hansen, 2010). Also, innovations were appropriated by the teacher and transformed into her own practice, which according to Zehetmeier et al. (2015) evidences that the PDP achieved real effects.

In the framework of a STEM CPDP, we verified that it is possible to engage teachers with technological resources that enable the development of mathematical tasks, appropriate to the primary school syllabus. In this regard, technology resources may innovate the teaching of mathematics (Fitzallen, 2015) and motivate students to learn this subject matter (Costa & Domingos,2017). In fact, teacher Marina recognized that students become more engaged with this kind of integrative approach. Finally, we conclude that technology may be used as a resource to promote mathematics teaching as exemplified by teacher Marina's case study.

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DOI: 10.17185/duepublico/70784
URN: urn:nbn:de:hbz:464-20191121-165623-4