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Photography as a tool to capture outdoor math: an experience with elementary preservice teachers

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Abstract

The literature mentions that taking pictures outdoors motivates students for mathematical learning and understanding. However, we do not yet have enough knowledge about how future teachers create mathematical tasks in real-life contexts. This paper, that is part of a broader project centered on active learning of mathematics outside the classroom, describes a study where elementary preservice teachers capture photos in the environment that allow task design. In particular, we want to identify which aspects of the environment were privileged by the future teachers' mathematical eye to support task design and to understand what are their main difficulties when designing mathematical tasks. Results suggest that the participants chose photos privileging elements related with buildings, which mobilized Geometry and Measurement contents. Participants stated that the use of photography had a positive impact on them, providing them with a more conscious and "closer look" at everyday objects, developing their "math eye", although they expressed that designing high cognitive level tasks is difficult.

Keywords: Photography; Outdoors mathematics; Task design; Problem solving; Teacher training.

Introduction

School mathematics requires effective teaching that engages students in meaningful learning through individual and collaborative experiences, giving them opportunities to communicate, reason, be creative, think critically, solve problems, make decisions, and make sense of mathematical ideas (NCTM, 2014). However, very often students don't develop such abilities, and they aren't able to make connections among different topics and use diversified tools to approach the same problem, since curriculum features and extension leads teachers to avoid this type of exploration. In this context, we must stress the importance of complementing learning with other environments, like the outdoors, since the classroom is just one of the "homes" where education takes place (Kenderov et al., 2009). The process of acquiring information and the development of knowledge by students can occur in many ways and in many places. Whereas the stimulus for an affective environment can influence the initial expectations and motivations of students, the use of the surroundings as an educational context can promote positive attitudes and additional motivation for the study of mathematics, allowing them to understand its applicability (Vale et al., 2015). The use of non-formal teaching contexts, such as the surrounding environment, constitutes an educational context that can foster positive attitudes among students, an additional motivation for the study of mathematics and, in particular, also contributes to the knowledge of the architectural, natural, and everyday heritage on the surroundings. Students need understanding and mathematical connections are fundamental to achieve this goal. In this scope, we consider that seeing the connection between the mathematics discovered in and outside the classroom through photos or images, and not viewing them as separate entities, can be a good learning strategy. Several researchers refer that photography outside the classroom motivates students for the understanding of math contents and contributes to seeing math through a new lens.

So, this work intends to promote contact with a contextualized mathematics, focusing on everyday life features, walking through and analyzing the place where we live, connecting some of its details through mathematical problem-solving tasks, designed by preservice teachers. The main purpose is to promote a new attitude towards mathematics, through the observation and exploration of the urban environment. It is important that future teachers are aware of the mathematics around them, with all the complexity but also beauty and challenge that it encloses. It is also an opportunity for students to formulate problems, which implies making decisions about what to consider and what to ignore in the situation under study, applying and mobilizing personal mathematical knowledge in the face of a situation, specifically a realistic one, and promotes creativity in its different dimensions. This provides the engagement of students in an active learning of mathematics, assuming that learning emerges from experiences and interactions between the intellectual, social and physical dimensions (Vale & Barbosa, 2020b, 2020c). So, we believe that through tasks that incorporate photography, along with challenging open-ended problem solving and posing tasks that promote cognitive abilities and encourage creative thinking which may contribute to the development of a positive attitude toward mathematics.

The aim of this study was to capture photographs in the environment that allow the formulation of mathematical tasks, in order to establish connections between mathematics and reality, which led us to the following questions: 1) What characteristics of the environment were privileged by the preservice teachers' mathematical eye?; 2) How can we characterize the main difficulties they experienced during task design; and 3) How can we characterize the preservice teachers' reactions revealed during this experience?

Outdoors a context for rich experiences

Learning mathematics is a lot about discovering, using and understanding mathematical contents in and through the students' daily environment and, in this sense, the idea of Outdoor Mathematics has gained popularity (Barbosa et al., 2022). This is a context that offers rich learning experiences to the participants, with the advantage of enabling the exploration of mathematical concepts stated in the curricular guidelines, aspect that can be seen as an advantage in the teachers' perspective (e.g. Vale et al., 2019). By experiencing mathematics outdoors, mainly through a trail, the participants can use and apply mathematical knowledge learned in school and also mobilize informal daily life knowledge. We consider a math trail to be a sequence of tasks along a pre-planned route (with beginning and end), composed of a set of stops in which students solve mathematical tasks in the environment that surrounds them (Vale et al., 2019, adapted from Cross, 1997).

Beyond this possibility there is a wide range of skills summoned by outdoor education like problem solving, critical thinking, collaboration, communication, reasoning or establishing connections. For all the stated reasons, we must consider that it is important to complement the work developed inside the classroom with experiences in the outdoors, allowing students to discover and interpret the world beyond those four walls and accepting that education can take place in different contexts (Kenderov et al., 2009).

In a math trail the participants come into contact with realistic problems that highlight the usefulness of mathematics, but more than that amplify the possibility of establishing connections between mathematics and reality. This feature can be a game changer in inducing positive attitudes towards this discipline (e.g. Bonotto, 2001), relying specially on curiosity, motivation and interest. Beyond solving realistic problems, in this context we must not forget the influence produced by movement in students' attitudes. Thinking and learning 'are not just in the head'; on the contrary, the body plays a decisive role in the entire intellectual process, from the first to the last years of our lives. Students who move, either in the classroom or in the outdoors, can learn, regardless of their activity, more effectively than those in typically sedentary classrooms (Hannaford, 2005). Alongside cognitive engagement, math trails bring into the table two other dimensions: physical and social engagement (Hannaford, 2005). The interaction between these dimensions, facilitated by a math trail, is in line with active learning, known by committing students to the learning process, hence promoting positive attitudes towards mathematics (e.g. Vale & Barbosa, 2020a). In addition to the mathematical learning benefits pointed out, the tasks outside the classroom, whether or not they are organized in a trail, contribute to the knowledge of the historical, architectural, and natural heritage of the place where the activities take place, contextualized in a realistic environment.

Photography and visualization

Several researchers (e.g. Meier et al., 2018; Munakata & Vaidya, 2012; Rizzo et al., 2019) have been working on photography outside the classroom as a way to motivate students, increasing interest and understanding of content, through the connection between mathematics and everyday situations. In addition, this type of approach gives students the opportunity to conduct their own transformative and aesthetic experience. This type of photograph, that we call mathematical photography (or problem picture), is a photograph of an object, phenomenon or situation that is accompanied by one or more questions or a problem based on the context of the photograph (adapted from Bragg & Nicol, 2011). According to these authors, an image-based question can stimulate students' curiosity in answering the question, as well as their engagement during the process of creating immediate questions or a problem. Gutstein (2006) argues that good tasks do not necessarily reside in the task itself but rather in the relationship between the task and the solver (student or teacher), related to students' interests and lives, aspect that reinforces the use of photos (digital images), because they are chosen by the user. Taking a photo creates an affective connection between everyday situations and mathematical concepts, which engages students with the tasks (Vale & Barbosa, 2020a, 2020b).

Visualization plays an important role in many subjects and areas, specifically through the crucial impact of images. In particular, in mathematics learning, visualization has been a subject of much undeniable discussion because the need to think and reason visually in problem solving is much stronger, and it can be a very important cognitive tool in the development of mathematical concepts and processes, including problem solving, not only in mathematics education but in a variety of areas (e.g. Arcavi, 2003). According to Arcavi (2003) visualization can be considered as a tool of thinking in the sense that is fundamental in the process of mathematical discovery, involving components of creative thinking.

For most people the mathematics that surrounds them often remains "invisible" to the untrained or inattentive eye, so we have to educate their gaze, i.e. their mathematical eye, so that they can identify contexts and elements that can support rich mathematical tasks (Vale & Barbosa, 2020b, 2020c). Developing a mathematical eye is an actual competence that students must acquire, because we live in a world where the visual features are a crucial component in the society and also in many professions. We use here the common term “mathematical eye” when we want to refer to use a mathematics as a lens to see and interpret many of the things that surround us. Connected with that term there is another, also widely used in a specific case, the "geometrical eye", a term that translates the power of seeing geometrical properties detach themselves from a figure. So, when we say that students must develop their mathematical or geometrical eye it means that we have to discover new ways of looking and consider familiar things, either in daily life, work or inside/outside the classroom. It means seeing common objects from a new perspective, whose level of detail varies with each individual's knowledge and experience. Barnbaum (2010) uses the metaphor of a detective when observing a crime scene. The detective will see a lot more detail than an ordinary person. He also refers that the art of re-seeing must be taught. According to Arcavi (2003) visualization must become more visible in the teaching of mathematics. He discusses mathematical visualization in a more figurative and deeper sense, as *seeing the unseen*, not only what comes *within sight* but also what we are unable to see, and become a tool for students to learn mathematics (Vale et al., 2018).

Using photos (images) provides opportunities to use the real world as the starting point and context to develop the mathematical eye and build mathematical problems and for further mathematical development, providing teachers with knowledge about students' visual attention. Furthermore, according with Meier et al. (2018) the use of photography motivates students, increases creativity and provides that "everyday life outdoors and science/mathematics can be connected in a meaningful way through the experience of photography" (p. 147). An image, real – object, situation or phenomenon - photography, drawing) has a fundamental importance in solving and formulating problems. In this particular case, we are interested in the use of photography. So, the ability to see, contributes to the identification of mathematics in everyday life, reinforcing this type of connections, which leads to the use of new approaches to teach and learn mathematics (e.g. Barbosa & Vale, 2018).

The design of tasks through photos

We defend that students must have mathematical experiences outside the classroom getting to know the natural, architectonic heritage surrounding their schools, and discover the connections of school mathematics with buildings, gardens, streets, solving tasks in real contexts. Hence, it is important that preservice teachers apply their knowledge about problem posing and creating tasks outside the classroom, so they can design tasks and trails for their own students.

For the design of tasks, we follow the ideas of Sullivan and Liburn (2002) and also some authors for problem solving (Brown & Walter, 2005; Silver, 1997; Stoyanova, 1998) that embrace all kinds of tasks, from simple exercises to challenging problems. Silver (1997) considers problem posing either being the generation (creation) of a new problem or the reformulation of a given problem. Stoyanova (1998) considers problem posing as the process by which, on the basis of mathematical experience, students construct personal interpretations of concrete situations and formulate them as meaningful mathematical problems. The formulation (design, elaboration, creation) of problems can be considered as the process by which, students construct mathematical interpretations of concrete situations based on their personal mathematical experiences and knowledge (e.g. Brown & Walter, 2005; Silver, 1997; Stoyanova, 1998).

Brown and Walter (2005) propose two strategies for formulating problems. The first strategy, *Accepting the given*, starts from a static situation, which can be an expression, a table, a condition, an image, a diagram, a phrase, a calculation or simply a set of data, from which we formulate questions in order to have a problem, without changing the starting situation. The second strategy, *What-if-not*, extends a given task by changing what is given. From the information contained in a problem, we identify what is known, what is asked for and what limitations the response to the problem involves. By modifying one or more of these aspects or questions, new and more questions can be generated (Barbosa & Vale, 2018; Vale et. al, 2015). Sullivan and Liburn (2002) there are three main features for posing good questions, that require more than remembering a fact or reproducing a skill. Students can learn by answering the questions, and the teacher learns about each student from their attempts. These authors propose a practical and accessible method for posing open-ended questions using a three-step process: (1) Method 1- *Working Backward*, which includes identifying a topic, thinking of a closed question and writing down the answer and making up a question that includes (or addresses) the answer; and (2) Method 2- *Adapting a Standard Question*, includes identifying a topic, thinking of a standard question and adapting it to make a good question.

These methods can also provide information about the way we choose a mathematical object translated into a mathematical photography, and if we look for the math potential of an object (or phenomena) in a photo or if we look for an object that matches a predefined math content.

Methodology and main results

This study adopted a qualitative methodology of exploratory nature (Erickson, 1986) with a group of 13 students from an initial teacher training course of elementary education (6-12 years), carried out in a school of education in a curricular unit of Didactics of Mathematics (Vale & Barbosa, 2019; 2020b, 2020c).Throughout the classes, these students were provided with diversified experiences, organized in curricular modules, focusing on problem posing and solving, learning outside the classroom, creativity, and the establishment of connections, particularly those involving mathematics and daily life; and other mathematical processes (e.g. communication, reasoning, representations). For this paper, we choose a proposal of tasks presented to the students that constituted a new experience for these future teachers - to create a *Photography task poster*. The proposed tasks should cover the elementary students' level (6-12 years).

The preservice teachers were asked, in pairs: 1) to explore the surroundings, taking a city tour analyzing the urban area where they had to capture a set of life shots, with potential to formulate mathematical tasks. They captured those photos with their mobile phones; 2) to choose some of the photos. The choices resulted from the analysis of the mathematics underlying each photo and the group discussion; 3) to formulate the tasks and solve them. In order to create a task using photos we used the respective picture, applying the problem posing strategy *accepting the given* (Brown & Walter, 2005) and then the future teachers used Method 1 or Method 2 to pose questions (Sullivan & Liburn, 2002); 4) each pair created a poster that should include photographs, the created tasks and solutions; 5) the posters were presented, discussed and evaluated by all the students who participated in this experience, using an assessment grid that focused on the assessment of the tasks and the poster in global terms. At the end, the future teachers also made a written report. Figure 1 shows one example illustrating the different moments of this experience, namely some objects chosen along the city tour, a photography task, and two moments during the class when they were observing the different tasks in the posters and assessing the posters.

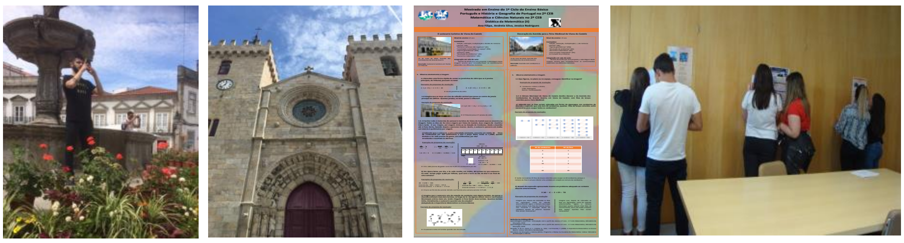

Figure 1. Examples of the different moments of the activity

Data was collected in a holistic, descriptive and interpretive way and included observations along the experience (except the poster printing), the set of photos chosen, the written report (describing their reaction throughout the different phases of the experience, including how they chose and created the tasks) and the assessment grid. All the data were analyzed in an inductive way according to the nature of that data and the research questions that we wanted to characterize.

Analyzing the photographs chosen by the preservice teachers in the presented posters, it appears that their gaze focused mainly on elements such as buildings/facades, flower boxes, and prices disposed on stores with information that could be explored mathematically. The participants supported this selection by referring to the mathematical content suggested by the captured images. They mentioned that these photographs were the ones that most inspired them for the contents that allowed to formulate the tasks. Through this dynamic, the objects of reality were transformed into mathematical objects, having aroused, for the most part, the mobilization of contents within the scope of Geometry and Measurement, followed by Numbers and Operations. In this sense, the establishment of connections between mathematics and real life was facilitated, being explored in a significant way through photography.

Figure 2 shows four of the tasks created by the students. We consider that the first two tasks have a low level of demand and also have another characteristic, which is the possibility of being solved without being present on the local. The other two tasks can be considered them of a high level of demand and the solver needs to be on site to collect the necessary data to solve it.

 The flower box shows a pattern where you can see symmetry of reflection and of rotation. Characterize all the symmetries you see.	 Margarida received a gift for her birthday of one hundred euros and forty cents. With this money, she decided to go shopping at a fashion store, with a price table shown in the image. Help Margarida decide what she can buy in the store with the money received.
 In the flower bed you can see some flowers. Find out which part of the flower bed occupies each group of flowers and then find out which area of the flower bed has no flowers. Explain your reasoning.	 Watch the avenue closely. For the Medieval Fair, the Avenue will be decorated with ribbons of colored handkerchiefs placed in a zigzag pattern supported on the lamps along the avenue (1 ribbon for every two lamps). How many tapes will it take to turn on all the lamps?

Figure 2. Examples of tasks proposed by the students

The formulation of tasks was not an easy process for these future teachers, a situation that can be explained by the fact that they did not have much experience at this level. Since the formulation of problems is a higher order ability, it implies regular work in order to have a positive impact on the quality of the proposals. For this reason, they expressed difficulties in going beyond traditional tasks, showing lack of creativity and reduced flexibility in the mobilization of different contents. In agreement with the ideas advocated by Barnbaum (2010), the more knowledge, training and experience we have, the more detailed and deeper the look will be. Despite having had the opportunity to contact with the objects in a real context, some of the pairs were unable to adapt the data used in the tasks to reality, having mobilized information that was not real (e.g. associating 3 meters in length to the radius of a flower pot).

We can, however, point out that some of the students were able to formulate challenging tasks with multiple approaches.

Some concluding remarks

To conclude, we will synthesize the main ideas taking into consideration the research questions that guided the study, and the data that emerged from the empirical work (Vale & Barbosa, 2020b, 2020c).

The main features of the environment privileged by the preservice teacher's mathematical eye were objects, in particular buildings (architecture). Students admitted that formulating high-level cognitive tasks was a difficult endeavor. Some were not able to adapt the data used in the tasks to reality, mobilizing information that was not real or accurate. The greatest difficulties resulted from the little experience they had in terms of task design, beyond tasks that involve formulas or calculations.

The choice of photos was based on "possibilities for good questions". Only one group chose photos that "fit" what they had already thought of proposing. In general terms, it was a successful experiment that allowed these future teachers to identify the potential of photography in the mathematical exploration of everyday objects. The use of photography as a means for promoting learning in Mathematics had a positive impact on students, providing a "closer look" for everyday objects, discovering the underlying mathematics in a more conscious and intentional way.

We may conclude that the students reacted with interest and motivation to the proposed challenge, committing themselves to the formulation of tasks. Based on the photos taken, they managed to build tasks suitable to explore mathematical contents for elementary students, being able to naturally highlight connections between mathematics and the environment. It was an opportunity for these them to experience other (teaching) learning contexts and also an opportunity for them to work together, create their own tasks, grounded on their personal perceptions of reality, posing questions and problems, and think creatively.

This study reinforced our understanding that photograph outdoors can assist students in task design as a significant aspect for developing the mathematics curriculum and of our practice as teacher educators. However, we continue to need more studies to help us include an instruction for teachers, and future teachers, to develop their "mathematical eye," as well as to create rich tasks suitable for elementary school students in the context of mathematics education outside the classroom. On the other hand, teacher education programs should provide opportunities for didactic experiences during instruction that stimulate the knowledge of (future) teachers-in-training, using and solving the same tasks and applying the same principles of teaching and learning that they are expected to use with their own (future) students.

As Bragg and Nicol (2011), we believe that through creating problem photos, teachers and students will see mathematics through a new lens.

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