INNOVATIVE PRACTICES IN DEVELOPING CREATIVE THINKING IN MATHEMATICS LEARNING

PRÁTICAS INOVADORAS NO DESENVOLVIMENTO DO PENSAMENTO CRIATIVO NA APRENDIZAGEM DA MATEMÁTICA

PRÁCTICAS INNOVADORAS EN EL DESARROLLO DEL PENSAMIENTO CREATIVO EN EL APRENDIZAJE DE MATEMÁTICAS

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ABSTRACT: Continuing education as a space for attentive reflection needs to provide teachers with implications and inferences for the student to be at the center of the learning process. Based on this assumption, this article aims to reflect on the importance of innovative practices for the development of creative thinking and mathematics learning with teachers in continuing education. Supported by documentary research and a qualitative approach, this research highlights experiences experienced in teacher training through innovative practices and the development of creative thinking. The discussions presented are the result of the authors' reflections based on various training sessions carried out in recent years, so that the methodology used was in and through action, of a collaborative-participatory nature. This article constitutes an auxiliary document for the continuing education of teachers, pointing out the importance of exploring innovative practices with teachers so that they can experience, discuss and create proposals for the development of creative thinking.

KEYWORDS: Teaching Mathematics. Innovative practices. Creative thinking. Teacher educacion. Problem solving.

RESUMO: *A formação continuada como espaço de reflexão atenta, precisa prover junto aos professores, implicações e inferências de o estudante estar no centro do processo de aprendizado. Partindo desse pressuposto, este artigo tem como objetivo refletir sobre a importância de práticas inovadoras para o desenvolvimento do pensamento criativo e aprendizagem da Matemática com professores em formação continuada. Apoiada na pesquisa documental e de abordagem qualitativa, esta pesquisa destaca vivências experienciadas nas formações de professores por meio de práticas inovadoras e no desenvolvimento do pensamento criativo. As discussões apresentadas são fruto da reflexão das autoras a partir de várias formações realizadas e a metodologia utilizada foi na e pela ação, de cunho colaborativo-participativo. Este artigo se constitui um documento auxiliar para a formação continuada do professor, apontando a importância de se explorar práticas inovadores junto aos professores para que eles vivenciem, discutam e criem propostas de desenvolvimento do pensamento criativo.*

PALAVRAS-CHAVE: *Ensino de Matemática. Práticas inovadoras. Pensamento criativo. Formação de professores. Resolução de problemas.*

RESUMEN: *La educación continua, como espacio de reflexión atenta, debe proporcionar, junto con los docentes, implicaciones e inferencias de que el estudiante está en el centro del proceso de aprendizaje. Partiendo de esta premisa, este artículo pretende reflexionar sobre la importancia de las prácticas innovadoras para el desarrollo del pensamiento creativo y el aprendizaje de las Matemáticas con los docentes en formación continua. Apoyada en la investigación documental y un enfoque cualitativo, esta investigación destaca las experiencias vividas en la formación docente a través de prácticas innovadoras y el desarrollo del pensamiento creativo. Las discusiones presentadas son el resultado de la reflexión de los autores a partir de diversas capacitaciones realizadas y la metodología utilizada fue en y por la acción, de carácter colaborativo-participativo. Este artículo es un documento auxiliar para la formación continua de los docentes, señalando la importancia de explorar prácticas innovadoras con los docentes para que experimenten, discutan y creen propuestas para el desarrollo del pensamiento creativo.*

PALABRAS CLAVE: *Enseñar Matemáticas. Prácticas innovadoras. Pensamiento creativo. Formación de profesores. Resolución de problemas.*

Introduction

There is an increasing search for Mathematics teaching that leads to learning with understanding and that explores other skills, the development of creative thinking being one of them (Costa; Silva; Gontijo, 2021). Van de Walle (2009) states that understanding consists of the quantity and quality of connections developed between new knowledge and what we already have. Therefore, when teaching Mathematics, it is important to carry out a practice that leads the student to go beyond knowledge that you already have, not limited to the development of an algorithm. Hoffmann and Silva (2023, p. 529, our translation) complement by stating that

> Learning with understanding means understanding *why* and *for what*, enabling the knowledge built in the classroom to also be useful beyond the school walls, enabling the student to justify why an answer is correct or a mathematical rule makes sense.

In this way, learning with understanding denotes an attitude of commitment to others, and pedagogical processes contribute to the construction of knowledge for life, as the student establishes a relationship with the contents worked on in the classroom and their daily lives.

Regarding creativity, there are different understandings of its meaning. One of them relates it to a skill that involves the development of non-standard ideas, showing previously unthought-of possibilities, associating it with people who have an innate capacity in a certain area. Another, defended by Silver (1994), Torre (2005), Gontijo *et al*. (2019) and Bicer (2021) identifies it as the result of work that involves time, reflection and flexible knowledge in a field of knowledge, allowing everyone to become creative. We share with researchers who defend the second conception and understand that it can be developed at school, in all curricular components, including Mathematics classes.

Combining learning with understanding means, in order to understand the why and what for defined by Hoffmann and Silva (2023) and the creativity of Silver (1994), Torre (2005), Gontijo, *et al*. (2019) and Bicer (2021), as constitutive elements of learning Mathematics as an attribute of a social good, we will have a great meaning here that explains the reason for things. It is in this essence that the relevance of learning Mathematics stands out, committing to relevant knowledge. In other words, what Morin (2011) considers one of the seven essential pieces of knowledge for what he defined as education of the future. For Morin (2011), relevant knowledge is not limited to the context alone. Therefore, the author makes reference to the global, stating that it is constituted by the union of parts that relate to each other, forming an organized whole, which is constantly restructured.

However, what we find in many schools, including in the early years of Elementary School, is Mathematics teaching based on the assumptions of the formalist technical tendency, presented by Fiorentini (1995), with an excessive concern in the exploration of algorithms and formal language, to the detriment of understanding that also involves social, historical and political knowledge.

This type of teaching does not contribute to knowledgeable learning, since it is concerned that students "do" it, that is, performing the technique is the main objective and not the whys in relation to how this technique is structured and why it is used. It also does not develop creative thinking, which, according to Silver (1994), is characterized by *fluidity*, *flexibility* and *novelty*, when solving a given problem. This is because in a class based on this understanding the student is limited to reproducing what was presented by the teacher.

For teachers to teach in a way that develops mathematical learning with understanding and creative thinking, it is necessary for them to carry out innovative practices in their classes, which lead the student to become protagonists in the process and co-responsible for their learning. In this sense, it is important to think about learning linked to teaching, which makes the strategies and proposals developed by teachers for their practices important elements in this process. Therefore, the objective of this study is to reflect on the importance of innovative practices for the development of creative thinking and learning Mathematics, with teachers in continuing education.

In order to highlight "Innovative practices in the development of creative thinking in learning Mathematics", the concepts of creativity, the relevance of learning Mathematics, and innovative practices are initially presented. Next, we describe the methodological procedures of this research and then present the theoretical foundation and discussions. The purpose of the section "Training teachers with experience in practices that explore problem solving" is to share their intentions and investigate their own pedagogical practice in order to qualify the teaching and learning processes. Subsequently, there is problem solving, a methodology for developing critical thinking in Mathematics classes. To conclude, the "Final Remarks" follow with the relevant contributions and observations from this research.

Methodological procedures

This research presented a qualitative approach as it seeks to analyze both the process and the result (Bogdan; Biklen, 1994). Regarding the procedure, it is configured as documentary and participatory research. It is documentary since official documents were researched in relation to teacher training and Mathematics teaching in the early years of Elementary School, as well as studies related to the themes discussed in this article. It is also characterized as a participatory study, since we directly analyzed several continuing education courses carried out with teachers who teach Mathematics in the early years of Elementary School.

Ten ongoing training courses were carried out, consisting of more than one meeting, in 2022 and 2023, using the methodology of developing innovative practical experiences that were carried out and analyzed together with teachers. Based on these experiences, theoretical and pedagogical discussions were held in the school context in which the teachers were working, also seeking to analyze the potential of practices for mathematical learning and the development of creativity. Around 500 teachers from four municipalities participated in these trainings.

The analyzes were carried out based on the teachers' statements and the analysis of practices carried out and socialized by them based on what was discussed in the first meetings.

Training teachers with experience in practices that explore problem solving

Carrying out practices involving methodologies that lead students to be protagonists and co-responsible for their learning have great potential to develop learning with understanding, as well as creative thinking, as they investigate, seek strategies, question and analyze. In relation to the teaching of Mathematics, many methodologies and strategies have been developed based on the following principles: problem solving, investigation, modeling, carrying out projects, etc.

In this context, we will focus on teaching Mathematics through problem solving, since, according to the National Common Curricular Base – BNCC (Brazil, 2018), a document that guides teaching in Brazil since 2018, it appears both as teaching strategy, as well as skills to be acquired. In relation to skill, in this document it appears several times in all school years, in relation to the teaching of Mathematics, also pointing out the importance of exploring the elaboration of problems, in the sense of leading students themselves to create their own, based on the principle that for them to be able to carry out this task, they need to have a certain knowledge about the content involved.

In view of the above, this document rectifies the need to explore problem solving in the teaching of Mathematics, from the first year of Elementary School, to understand the concepts and processes related to Mathematics.

The ability to solve problems is an increasingly desired skill in today's society, as it allows people to solve problems and develop creative thinking, seeking new alternatives. Understanding ability "as complex mental structures that constitute a synthesis of the properties and qualities of the mind; therefore, they include several aspects developed during the proper execution of an activity" (Brito, 2011, p. 44, our translation), we understand that it is not something innate in humans, it needs to be developed and, for this, it is important that the school works in this direction.

Regarding problem solving as a teaching and learning strategy for Mathematics, there are different conceptions on how to explore it. Among them, we have one that understands it as a methodology that starts from the exploration of knowledge based on the discussion of strategies developed by students to solve a problem, called a generating problem. A generative problem is the one presented at the beginning and which allows, as Allevato and Onuchic (2021) present, through its resolution, the construction of new knowledge.

We believe that this conception is what contributes to the learning of Mathematics. It is important to highlight that in it the problem is taken as, according to Lester (1977, 1980 *apud* Possamai; Allevato, 2022), a situation that a person needs and wants to resolve, but is not yet clear what strategy to follow.

In this context, the problem means the relationship constituted between what is presented and who needs to solve it, and problem solving for the teaching of Mathematics is the process of searching for the solution, which "[...] involves, in addition to the mobilization of prior knowledge of the solver, *creativity and decision-making*, affective issues in the relationship with the problem" (Possamai; Allevato , 2022, p. 6, emphasis added, our translation).

However, for many teachers who teach Mathematics in the early years of Elementary School, this perspective, despite having been studied in Brazil for over 50 years, is still characterized as an innovative practice, since their experience with solving problems in classroom was that of problems with statements, listed in textbooks at the end of the chapter, as a way of exploring the subject presented. Possamai and Allevato (2022) reinforce this statement when they report that many Mathematics teachers understand mathematical situations related to statements that present data that students must select to carry out a mathematical

procedure as problems. According to the authors, in this case we have a fixation exercise, as students already know what should be done.

Therefore, there is a need to help teachers who were not aware of this potential to explore Mathematics, to understand its importance for learning with student understanding and to change their attitudes in the classroom. Changing attitudes becomes necessary because, according to Brito (2011), it is related to a person's affection towards something or someone, while beliefs and values refer to cognitive issues. Therefore, it is important to work with teachers on the relationship they have with this science, since the experience in continuing education shows us that many teachers who work in the early years of Elementary School understand Mathematics as something difficult to learn and understand, due to the experience they had as students.

Under these conditions, we emphasize the importance of continued training for teachers who teach mathematics to carry out experiences in practices that explore problem solving to, from there, discuss the theoretical and pedagogical knowledge involved, then moving on to carry out new practices, based on the discussions carried out. We understand that this process can lead them to have new experiences, as something that touches and modifies them (Larrosa, 2002), so that, in class, their students can also better understand this science, as well as develop their creative thinking, as Both knowledge and creativity will be important at all times in life.

Brito (2011) states that students have various skills and school institutions must be concerned about valuing them. The creative skill that involves developing a new resolution strategy or a new product is as important as the skills that involve knowledge of content. To this end, engendering continued training with teachers who teach mathematics involves a positive and innovative attitude towards the changing reality itself, considering that the construction and strengthening of professional identity are part of teacher professionalization, as innovative practices and Creative ideas become components of the construction of professional and personal knowledge.

> Continuing training as a modality that constitutes itself and is constituted by the subjects of this training, is at the same time the whole and the part. They point out the different possibilities they take into account, space and time as important aspects for organizing, programming and implementing training and thus guaranteeing the construction of knowledge both at a professional and personal level (Simão, 2012, p. 627, our translation).

Nóvoa (2002) suggests the importance of the effort to develop innovative practices of reflection and deliberative transposition, transforming training into a moment in which individual practices and opinions are taken into consideration and are the focus of discussion, where there is sharing of ideas and opinions. The sharing by the teacher who teaches Mathematics of his educational practice, clarifying his intentions and his investigation of his own practice portrays pedagogical, social and investigative responsibility. The self-assessment process is seen as an instrument for reflection on pedagogical practice and guides important points for the context of learning. For this self-assessment, pedagogical practices need to be taken into consideration, in order to reflect on the means and not just the end of pedagogical processes.

The prominent knowledge of practice and experience is a privileged space in the work of the teacher who teaches mathematics, because it arises from the daily life of his profession, which is why reflection on practice is a central element for the integral formation of the subject.

Learning is something that the subject builds for himself in interaction with the information that the environment makes available (Maturana; Varela, 2001). In other words, the subject constructs his own knowledge, dialoguing with those presented to him. In this context, creative and innovative pedagogical practices require teachers not only to have the ability to teach, but to develop creativity, enabling students to construct, deconstruct and reconstruct knowledge.

Problem solving, a methodology for developing creative thinking in mathematics classes

As announced in the previous section, we understand creativity as a skill that can be developed and also as an intrinsically human attribute that allows us to create and transform the environment. For Torre (2005, p. 58, our translation) “Creativity is a human potential, and like education, it is an attribute of rational beings”. In this way, it is understood that being creative requires self-determination and all creative dynamism has an innovative condition, understanding creativity as a social good that promotes human and scientific development.

Based on this assumption, we understand that teachers have an important role in this process, to carry out practices that enable their development. To achieve this, it is important that they have knowledge of the key components of creative thinking, which are: fluency, flexibility, *and* novelty (Silver, 1994) and; how to develop them.

Silver (1994) explains that, in general, *fluency* is related to the different strategies and responses presented, while *flexibility* refers to the ease of adapting to the changes presented, generating responses to a given *prompt* and; The *novelty* is seen in the originality of the answers presented.

Problem solving, when used as a Mathematics teaching methodology in which, "learning occurs during the process of attempting to solve problems in which relevant mathematical concepts and skills are incorporated" (Lester; Cai, 2016, p. 119, our translation), enables the development of creative thinking through a process of investigation, discussion, recording of resolution and argumentation. In this sense, proposing problems also gains importance, understood as an idea that goes beyond elaboration, sometimes presented as a necessary skill by the BNCC, since it involves, according to Allevato and Possamai (2022) the creation, formulation and elaboration of a problem, that is, organization of ideas, structuring and writing, making an association between mother tongue and mathematical language.

Silver (1994), already in the 1990s, argued that the interaction between formulation, attempted resolution, reformulation and problem solving was important for the development of creativity, since it is associated with both processes and products.

In relation to the key components of creative thinking, it can be said that creative *fluency* is related to the number of ideas that arise from a request. Flexibility is found in the different forms of representation and in the different strategies used to generate a response from the initial information and *novelty* refers to the various ways of presenting the solution, when it is unique, or multiple solutions to open problems (Costa; Silva; Gontijo, 2021); It should be noted that the development of mathematical creativity in the classroom refers to the

> ability to generate new mathematical ideas, processes, or products that are new to students, but may not necessarily be new to the rest of the world, by discerning and selecting acceptable mathematical patterns and models. Because the emphasis of this definition is on students' intellectual development in mathematics rather than on the development of new or useful mathematical products, this definition will further support mathematical equity, since 'the implication for equity in mathematics education is that all students must have access to mathematics' (Bicer, 2021, p. 253, our translation).

Along this path, it is up to the teacher to work with open and poorly structured problems, in addition to enabling the students themselves to propose their own problems, so that they have the possibility of seeking different paths and finding different solutions. It is also important to

help, without providing ready-made answers or indicating processes, as well as always encouraging, so that students do not become discouraged or see the error as something negative, but as a stage in the process (Hoffmann; Silva, 2023).

At this point, we return to the idea that in order for there to be learning with understanding and development of creativity by the student, it is important that the teacher is always providing feedback on his knowledge related to teaching. According to Lester and Cai (2016, p. 119, our translation), the teaching of Mathematics consists of several dimensions, which are: the characteristics of the tasks explored; the role of the teacher; the structure of the class; the mathematical tools that help learning and care in teaching with equity and accessible to all. This all reinforces the importance of continued training that analyzes and discusses the practices developed by teachers, that brings theoretical depth and that leads participants to experience innovative practices, addressing the possibility of implementation in the classroom.

The importance of training teachers who teach Mathematics with experiences, which they explore as a modality that is constituted and constituted by the subjects who are the whole and part of this training, suggests openness to the new. Bringing theoretical knowledge closer to real situations helps to transform, through problem solving, practical issues resulting from attentive and contextualized reflection. Thus, reflection, analysis, the ability to find answers to questions and, above all, the possibility of being attentive to the real situations in which each individual finds themselves, denotes being attentive so that the best results are obtained. For these reasons, investing in the continued training of teachers helps to bring closer and reflect their actions, in the search for an attitude of professional qualification towards the formation of an integral being.

Final remarks

In this research, we assume that teacher training is a fundamental part of promoting innovative practices in the development of creative thinking in learning Mathematics. The ability to solve problems is an increasingly desired skill in today's society, as it allows people to solve problems and develop creative thinking, seeking new alternatives. However, it is not something innate in humans, it needs to be developed and, for this, it is important that the school works in this direction.

In view of this, there is a need to help teachers who were not aware of the importance of exploring Mathematics in the classroom using this strategy, to understand its importance for

learning with student understanding and changing their attitudes in the classroom. In this research, the importance of continuing training for teachers who teach Mathematics is highlighted in carrying out experiences in practices that explore problem solving in order to, from there, discuss the theoretical and pedagogical knowledge involved, then moving on to carry out new practices, based on the discussions held.

It is noteworthy that the teacher who teaches Mathematics has the possibility of sharing his intentions and investigating his own pedagogical practice in order to qualify the teaching and learning processes, denoting pedagogical, social and investigative responsibility.

In the case of problem solving, learning occurs during the process of trying to see problems, incorporating relevant and meaningful concepts with the student. In relation to the key components of creative thinking, it can be stated that creative fluency is related to the number of ideas that arise from a request. Therefore, aiming for learning with understanding and development of creativity by the student, it is important that the teacher is always providing feedback on his knowledge related to teaching.

As a limitation of this study, we point out the training of many Basic Education teachers in relation to Mathematics and its teaching, which does not allow them to make connections between school and contextual knowledge to be explored in their pedagogical practice. This fact makes it impossible for relationships between the student's problem-solving ability and development of creative thinking to be stimulated. Another limitation was the difficulty in continuously monitoring the teachers' pedagogical practices, in a group with collaborative characteristics, for reflection and action on their own pedagogical practice, due to the fact that they have hours of institutional studies at different times. Finally, we affirm that longitudinal research on this topic is necessary to further deepen the analyzes and their developments.

It can be concluded that the construction of knowledge is an individual process that is constituted from lived and understood experiences and through dialogue and reflection. Due to this, it is necessary that the teacher who wishes to develop creative and innovative pedagogical practices has, himself, both the ability to stimulate and develop creativity, thus facilitating learning, construction, deconstruction and reconstruction of knowledge of students.

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