10.46551/emd.v9n17a13 ISSN 2526-6136

Educação Matemática Debate

The role of mathematical experimentation in the development of creativity

Karin Ritter Jelinek
Universidade Federal do Rio Grande
Porto Alegre, RS — Brasil
0000-0002-4853-2319
karinjelinek@furg.br

Received • 21/11/2024
Accepted • 07/04/2025
Published • 25/05/2025

Article

Abstract: Mathematics in Brazil is still predominantly taught from the perspective of transmission of knowledge, and differentiated practices are largely scarce in the classroom. In contrast to this concept, experimentation presents itself as an innovative methodology which puts students in the center of the learning process, allowing them to create hypotheses, devise their own strategies, and develop their argumentation and creativity. Manipulatives support this process, enabling the exploration of diverse strategies and innovative solutions. From this perspective, the study sought to understand how the basic curriculum of Brazil (BNCC) and international guidance documents treat the relation between experimental activities and the development of creativity in students. To this end, a qualitative approach was adopted using documentary research to analyze the selected primary sources. The results indicate that mathematical creativity is promoted when pedagogical practices value reasoning, reflection and experimentation.

Keywords: Mathematical Experimentation. Manipulatives. Reflection. Creativity.

El papel de la experimentación matemática en el desarrollo de la creatividad

Resumen: La enseñanza de la Matemática en Brasil todavía se encuentra predominantemente bajo la perspectiva de la transmisión de conocimiento, y las prácticas diferenciadas son, en gran medida, escasas en las aulas. En contraposición a esa concepción, la experimentación se presenta como una metodología innovadora, que pone al estudiante en el centro del proceso de aprendizaje, permitiéndole crear hipótesis, elaborar estrategias propias y desarrollar su argumentación y creatividad. Los materiales manipulables favorecen este proceso, permitiendo la exploración de diversas estrategias y soluciones innovadoras. En esa perspectiva, el estudio buscó comprender cómo la BNCC y los documentos orientadores internacionales tratan la relación entre actividades experimentales y el desarrollo de la creatividad en los estudiantes. Para eso, se adoptó un abordaje cualitativo, utilizando la investigación documental para el análisis de fuentes primarias seleccionadas. Los resultados indican que cuando las prácticas pedagógicas valorizan el raciocinio, la reflexión y la experimentación, se promueve la creatividad matemática.

Palabras clave: Experimentación Matemática. Materiales Manipulativos. Reflexión. Creatividad.

O papel da experimentação matemática no desenvolvimento da criatividade

Resumo: O ensino da Matemática no Brasil ainda está sob a perspectiva da transmissão de conhecimento. Em contraposição, a experimentação coloca o estudante no centro do processo de aprendizagem, permitindo-lhe criar hipóteses, elaborar estratégias próprias e desenvolver sua argumentação e criatividade. Os materiais manipuláveis favorecem esse processo, possibilitando a exploração de estratégias diversas e soluções inovadoras. Nessa perspectiva, o estudo buscou compreender como a BNCC e documentos orientadores internacionais tratam a relação entre atividades experimentais e o desenvolvimento da criatividade nos estudantes. Para isso, adotou-se uma abordagem qualitativa, utilizando a pesquisa documental para a análise de fontes primárias selecionadas. Os resultados indicam que a criatividade matemática é promovida quando as práticas pedagógicas valorizam o raciocínio, a reflexão e a

experimentação.

Palavras-chave: Experimentação Matemática. Materiais Manipulativos. Reflexão. Criatividade.

1 Some initial ideas

It is widely recognized that Mathematics classes, as they are currently conducted in schools, where the teacher's explanations followed by a list of exercises prevail, do not encourage openness to discussion or active participation by students. However, students' involvement in mathematical activities is noticeable when they allow them to express their thoughts and understanding, and to externalize the relationships they establish between concepts or between the concept studied and their lives.

When teaching is done through spoilers, telling the end of the story, that is, anticipating the outcome of mathematical learning — starting with the definition of the mathematical concept to be studied or the enunciation of a formula for solving it — students experience the same frustration as when receiving a spoiler for a recently released film. If the ending is already known, how can we maintain their interest and motivation to follow the journey?

In addition, it is necessary to reflect on students' readiness for the activities proposed in the classroom. Methodological strategies that do not allow students to be at the center of their learning process will hardly achieve the desired engagement and meaningful construction of learning.

Placing students at the center of their learning process means opening up their unique way of thinking mathematically. It means exploring different ways of approaching a situation, encouraging divergent thinking and mathematical creativity. In this context, creativity manifests itself as a complex, heterogeneous and multifaceted process, based on the criteria of *novelty* and *value* (Martinez, 2002). Furthermore, enabling moments of socialization, argumentation and listening to different perspectives contributes to the development of metacognition, expanding the ways of constructing mathematical knowledge.

Martinez (1995, 2008) argues that creativity is not a gift exclusive to a few, but a capacity that can be developed in all students. For her, creativity is closely related to problem solving and the stimulation of educational environments that encourage investigation, curiosity and freedom to think in an original way.

To promote creativity, teachers must create situations in which students can explore different strategies, formulate hypotheses and experiment with innovative solutions. Furthermore, it is important to value mistakes as part of the learning process and to encourage critical and reflective thinking (Martinez, 1995). In this context, it is important to reflect on which methodological strategies teachers can use to foster mathematical creativity in students.

In this sense, manipulative materials can make a significant contribution, creating opportunities for students to explore different strategies, formulate hypotheses and experiment with innovative solutions. By enabling interaction with concrete representations, these resources favor the active construction of knowledge and stimulate creativity in the mathematical learning process.

Considering that the use of these materials together with experimental activities can facilitate the integration of these ideas in Mathematics classes, the study presented here proposes the following question: *How do national and international guidance documents address the relationship between experimental activities and the development of students' creativity?*

2 Methodological design

Considering that this study aimed to understand the relationship between experimental activities and the development of students' creativity, it is characterized as a qualitative investigation. This approach is appropriate for the conceptual development and theoretical deepening intended. According to Esteban (2010, p. 127), qualitative research is defined as

> a systematic activity aimed at an in-depth understanding of educational and social phenomena, the transformation of socio-educational practices and scenarios, decision-making and, also, the discovery and development of an organized body of knowledge.

In this context, the documentary research method was adopted, characterized by its potential to analyze a wide variety of sources, including statistical tables, newspapers, magazines, reports, official documents, correspondence, films, photographs, paintings, tapestries, business reports and videos of television programs, among others (Fonseca, 2002). This method is based primarily on primary sources, that is, data and information that have not yet been scientifically analyzed or interpreted from specific perspectives.

Complementing this perspective, Cellard (2008) highlights that documentary research is especially useful when seeking to understand how certain themes are treated in institutional or historical documents, since it allows the analysis of the intentions, contexts and meanings attributed by the authors of the sources. To this end, the approach follows three main stages: pre-analysis, organization of the material and data processing.

In the pre-analysis stage, a survey of international curricular documents available online was carried out, aiming to identify materials that addressed the relationship between experimental activities and the development of creativity in the teaching of Mathematics. The material was then organized, at which point documents that explicitly addressed recommendations for the use of manipulative materials and experimental practices were selected.

Among the documents analyzed, the following stand out: publications by the National Council of Teachers of Mathematics (NCTM) of the United States, the guidelines of the Mathematics Working Group of the Portuguese Ministry of Education, and the guidelines of the Chilean Ministry of Education. In the last stage, a detailed analysis of the selected documents was carried out, with the aim of identifying the recommended approaches, as well as the explicit connections with the development of students' creativity.

Based on the analysis of the selected documents, it is understood that this methodology can prove powerful in enabling a broad and well-founded analysis, promoting reflection on the intersections between the educational policies of countries that seek to improve student learning rates in Mathematics and the recommended pedagogical practices in the field of Mathematics.

In addition to the international documentary analysis, we also sought to situate this study in relation to national academic production, through a search of publications in the journal *Educação Matemática Debate*. However, no studies were found using the descriptors: mathematical experimentation, experimental activities, mathematical experimentation and creativity, or mathematical experimentation and manipulative materials. This highlights the relevance of this study for the area.

3 Memorize less, reason more!

If the goal is to teach Mathematics that places students at the center of their learning process and that generates their effective engagement in class, it is necessary to seek teaching practices that promote less repetition and more creative mathematical reasoning. These practices must go beyond motivational or playful aspects, but focus mainly on the construction of mathematical notions and ideas, with an emphasis on the development of logical reasoning, argumentation and mathematical creativity in students.

An effective teaching resource to promote the development of these skills is manipulative materials and mathematical games. However, it is important to emphasize that, when dealing with these resources, not all games involve manipulative materials, nor is every manipulative material a game. Therefore, it is essential to make this distinction, since, although both are valuable instruments, their nature and function may vary.

According to the study proposed here, manipulative materials can be understood as "objects or things that the student is able to feel, touch, manipulate and move. They can be real objects that have everyday applications or they can be objects that are used to present an idea" (Reys[1] apud Matos and Serrazina, 1996, p. 193). In other words, these manipulative materials are those that provide students with physical involvement with the material and that aim, above all, to place them at the center of the learning process.

Camacho (2012, p. 25) also corroborates this view, highlighting that manipulative materials are

> playful, dynamic and intuitive objects, with application in our daily lives, which aim to assist in the construction and classification of certain concepts that, depending on their level of abstraction, require physical support to guide their understanding, formalization and structuring.

Manipulative materials are a catalyst for the construction of mathematical concepts and notions. Games have proven to be superior activities because they offer challenges to students, who participate freely and choose the rules of the game. Thus, "games stand out as activities in which children freely engage, seeking to overcome challenges of different types and under defined rules" (Jelinek, 2005, p. 122).

In short, manipulative materials and games are not synonymous. Manipulative materials, whether structured or not, are suitable for activities that aim to facilitate the student-knowledge relationship in the construction of mathematical knowledge. Games may even involve a mathematical concept, however, their difference lies in the rules mutually agreed upon by participants, in overcoming the challenges intrinsic to it, as well as in the student's freedom of choice to participate or not. Both, therefore, should be considered beyond the motivational or playful factor in Mathematics classes.

From this perspective, mathematical experimentation emerges as an activity in which mathematical notions and concepts are explored in different environments, such as classrooms, laboratories and, especially, in Mathematics Teaching Laboratories (LEM), defended by Lorenzato (2008, 2012). These mathematical experiments can involve practical activities that encourage students to understand abstract concepts, using games, puzzles, children's stories, manipulative materials (structured or not), open problem situations, among others. It is important to highlight that they are not stereotypical activities, in which there is a set of steps to be followed.

Lorenzato (2008, p. 72), when discussing some methodological principles for learning Mathematics, argues that it is necessary to encourage experimentation, which he defines as

[1] REYS, Robert E. Considerations for teaching using manipulative materials. *The Arithmetic Teacher*, v. 18, n. 8, p. 551-558, 1971.

"action on objects (manipulation), with an emphasis on observation, comparison, assembly, decomposition (separation), distribution". The author adds that the importance of these proposals lies in their power to provoke reasoning, reflection and the construction of knowledge.

This study understands that experimental practice involves proposals in which students engage in activities that require exploring, inferring, predicting, analyzing, presenting, comparing, deducing, relating, questioning, discovering, (re)thinking, communicating, negotiating and defending points of view, among others. In short, these are activities that are significantly different from traditional practices based on copying, solving, repeating and memorizing.

Furthermore, the student's participation in an experimental activity does not occur in a *theoretical vacuum*. He will engage, infer, conjecture, test, reflect and negotiate meanings based on his mathematical background. Consequently, the much-desired connection between concepts finds fertile ground to develop. In this context, the close relationship between experimentation and reflection becomes undeniable, as well as the construction of subjective meanings and creativity by students in relation to mathematical concepts.

This means that an experimental activity goes beyond the simple manipulation of materials. It calls upon reasoning! By calling upon it, the much-desired questions from students will occur. It is important to understand that questions are like *engines of thought*, since they trigger the construction of relationships and meanings with regard to mathematical thinking. Otherwise, it is necessary to combine the manipulation of materials (physical or virtual objects) with intellectual activity, seeking to guide the establishment of relationships with the notions and concepts that one wishes to construct.

As Pais (1996, p. 67) explains, "there is generally a great expectation that, with the use of this manipulation, the student can, by himself, and under pedagogical guidance, discover properties that, once abstracted, would contribute to conceptual elaboration". The author adds that, in fact, manipulative material is a facilitator given the immediacy offered by the object, considering that a study based on a drawing already implies a certain level of abstraction. In other words, manipulative materials do not contribute to mathematical learning without an experimental activity associated with their use.

Therefore, when proposing an experimental practice, the teacher values the process and not just the result of learning. Furthermore, this approach constitutes a powerful strategy for mobilizing students in proposals that position them as active subjects, at the center of the learning process, shedding light on creativity and authorial thinking in Mathematics. Naturally, this is a methodological proposal that may take longer to work on a given concept, however, the gain is notable in terms of student understanding.

4 The role of creativity in teaching Mathematics

In order to understand how the Base Nacional Comum Curricular *[National Common Curriculum Base — BNCC]* and international guidance documents address the relationship between experimental activities and the development of students' creativity, the guidelines contained in the BNCC were initially analyzed. Next, guidance documents from international institutions were considered, such as the National Council of Teachers of Mathematics in the United States, the Ministry of Education of Portugal, and the Ministry of Education of Chile.

To understand how experimental activities are addressed in the BNCC and what didactic guidelines are associated with them, it is already noted at the beginning of the Mathematics section that "it is also of fundamental importance to consider the heuristic role of experiments in learning Mathematics" (Brasil, 2017, p. 265). Although the document does not explicitly state what these experiments would be, there are references to the processes of problem-solving, investigation, project development, and modeling. These practices are considered privileged forms of mathematical activity, as they are highly enriching for the development of essential skills, such as reasoning, representation, communication and argumentation.

Among the eight specific Mathematics skills for Elementary Education (Brazil, 2017, p. 269), two of them deserve attention:

> 2. Develop logical reasoning, a spirit of inquiry and the ability to produce convincing arguments, using mathematical knowledge to understand and act in the world.
> 5. Use mathematical processes and tools, including available digital technologies, to model and solve everyday, social and other knowledge-related problems, validating strategies and results.

It is interesting to shed light on these Specific Competencies, given that they highlight the importance of ensuring that students know how to use mathematical tools and develop, in addition to their mathematical reasoning, their argumentative capacity and investigative spirit. However, it is necessary to understand how these competencies are expected to be worked on.

Further evidence is found in the passage from the document that deals with the specific guidelines for Mathematics in the Elementary Education (Brazil, 2017). In addition to having the record that mathematical learning must be deeply linked to understanding, it is equally interesting to note the indication that teaching resources, such as grids, abacuses, games, books, videos, calculators, spreadsheets and dynamic geometry software, play a fundamental role in the understanding of mathematical notions.

With regard to the recommendation for the use of these teaching resources, the document highlights that it is essential that these materials be incorporated into situations that favor reflection and systematization, with the aim of initiating a process of formalization. It is also worth mentioning that, in different skills from the 1st to the 4th grade of Elementary School, they point out that the development of a given concept should be supported by manipulative materials, such as "(EF02MA08) Solve and develop problems involving double, half, triple and third part, with the support of images or manipulative material, using personal strategies" (Brasil, 2017, p. 283).

Following the same approach, when dealing with specific guidelines for Mathematics in the Middle School (Brasil, 2017), it mentions that, in addition to grids, abacuses, games, calculators and dynamic geometry software, the history of Mathematics is important to spark interest and contextualize teaching. And again, it emphasizes that all these materials should be used in situations that promote reflection and help in the systematization and formalization of mathematical concepts.

Thus, the most recent document that guides education in Brazil recommends the use of teaching resources and suggests some specific materials. However, although it emphasizes the need to structure situations that encourage reflection, it does not explain how these proposals can be effectively implemented in the classroom. Therefore, the impasse mentioned above remains: although the relevance of using these materials is recognized, there is still a gap in concrete strategies to effectively implement them. Likewise, the heuristic role of experimentation in learning Mathematics is also not clearly outlined in the specific guidelines.

Regarding the development of students' mathematical creativity, no subsidies were found to guide teachers' practice. The document makes no reference to this skill. That said, it is interesting to investigate how international documents address these issues.

The National Council of Teachers of Mathematics (NCTM) is an internationally recognized American Mathematics Education organization that, since 1920, has sought to defend high-quality Mathematics teaching and learning for every student. Since the 1980s, the organization has published the NCTM's Standards, which present a vision based on the assumption that all students are capable of learning mathematics.

Among these publications, the following stand out: *Professional teaching standards* (1991), *Principles and Standards* (2000) and *Principles to actions: ensuring Mathematical success for all* (2014). The first publication aimed to become a reference in guiding the work of North American mathematics teachers in the 1990s, obtaining great repercussion, including in the global mathematics education community.

In 2000, the *Principles and Standards* (NCTM) were published, which, like the previous document, also sought to become a global reference for guiding quality mathematics teaching processes. To this end, the NCTM invested heavily in challenging the idea that mathematics is only for a select few. It began to argue that all students need to understand mathematics and should have the opportunity and support necessary to learn meaningful mathematics with depth and understanding. For the NCTM, there is no conflict between equity and excellence.

The publication in question proved to be a guide aimed at improving student performance in mathematics. It had an impact and presented six fundamental principles for high-quality mathematics education:

- *equity* — excellence in mathematics education requires equity — high expectations and strong support for all students;
- *curriculum* — a curriculum is more than a collection of activities; it should be coherent, focused on what is mathematically important, and well-articulated across grade levels;
- *teaching* — effective mathematics teaching requires understanding what students know and need to learn, and then challenging and supporting them to learn well;
- *learning* — students should learn mathematics with understanding, actively constructing new knowledge based on prior experiences and knowledge;
- *assessment* — assessment should support mathematics learning by providing useful information to both teachers and students;
- *technology* — technology is essential to the teaching and learning of mathematics; it influences the mathematics that is taught and enhances student learning.

In addition to the six principles, the document also indicated desirable standards for content and processes related to the teaching of mathematics. The following content standards were indicated: Numbers and Operations, Algebra, Geometry, Measurement and Data Analysis, and Probability. As procedural standards, it indicated Problem Solving, Reasoning and Demonstration, Communication, Connections, and finally, Representations (NCTM, 2000). The procedural standards entitled *Reasoning and Poof*, *Communication and Connections* deserve special attention within the scope of the study proposed here.

Regarding the *Reasoning and Proof* standard, the document highlights that mathematical reasoning and proofs are powerful ways of developing and expressing perceptions about a wide range of phenomena. Indeed, it is pertinent to consider that subjects who reason and think analytically tend to observe patterns, structures or regularities in both real-world and mathematical situations. The same applies to mathematical conjectures, since, when encouraged to investigate them, students develop and evaluate mathematical arguments and proofs — formal instruments for expressing particular types of reasoning and justification. This process contributes significantly to the construction of meaning in relation to mathematical concepts.

Another standard that deserves to be highlighted is *Communication*. According to the document under analysis, mathematical communication is a way of sharing ideas and clarifying and refining understanding. In fact, when students are challenged to communicate the results of their thinking to others, as their schooling progresses, they learn to be clear, convincing and precise in their use of mathematical language. At various stages of schooling, listening to others' explanations allows students to develop their own understanding. Conversations in which mathematical ideas are explored from multiple perspectives help participants sharpen their thinking and make desirable connections (NCTM, 2000).

The work with *Connections* helps to show that Mathematics is an integrated field of study. According to NCTM (2000), when students connect mathematical ideas, their understanding is deeper and more lasting, and they begin to see mathematics as a coherent whole. In this way, students can begin to see mathematical connections through the interaction between mathematical topics, in contexts that relate Mathematics to other disciplines and in their own interests and experiences.

Realizing that the published standards, by themselves, did not guarantee an improvement in the quality of students' mathematical understanding, in 2014 the NCTM launched the *Principles to actions: ensuring Mathematical success for all*. Thus, the principles of Mathematics Education were published that should guide educational work to ensure effective mathematical success for students. These actions are based on the *Principles and Standards*, a document that the NCTM (2000, p. 11) initially defined as a set of principles that "describe the characteristics of high-quality mathematics education".

Based on a review of this set of principles, based on more than a decade of experience and new research evidence, as well as significant obstacles and unproductive beliefs that continued to compromise progress in mathematics education, the *Guiding Principles for Mathematics Education* were structured: Teaching and Learning, Access and Equity, Curriculum, Tools and Technology, Assessment, and Professionalism. The document also describes the conditions, structures, and policies that must exist for all students to learn. Finally, it suggests specific actions that teachers need to take to ensure mathematical success for all.

Among the six *Guiding Principles* presented by the NCTM (2014), two deserve special attention in the context of the studies developed in this article:

- *teaching and learning* — an excellent mathematics program requires effective instruction that engages students in meaningful learning through individual and collaborative experiences that foster their ability to make sense of mathematical ideas and reason mathematically;
- *tools and technology* — an excellent mathematics program integrates the use of mathematical tools and technology as essential resources to help students learn and make sense of mathematical ideas, reason mathematically, and communicate their mathematical thinking.

These two principles are significant because they indicate that effective learning occurs through both individual and collaborative experiences. In a complementary manner, they highlight the importance of integrating the use of tools and technologies that help students develop mathematical reasoning into mathematics teaching.

In other words, these principles deserve attention because they address not only the use of resources, but also the procedures that involve these instruments. They are strongly related to the issues that this study seeks to explore, although in a diffuse and non-explicit way, but are nevertheless highlighted as elements that contribute to the mathematical learning of all students.

In short, the analysis of this set of NCTM documents reveals that learning should promote the construction of new mathematical knowledge based on students' experiences. In this sense, the procedural standards emphasize the importance of fostering the development of reasoning, communication, and connections to achieve quality mathematical learning. However, in the 2014 publication, there is explicit guidance that teaching and learning practices should be based on individual and collective experiences, and that the use of *tools* is essential for students to understand and attribute meaning to mathematical ideas.

Similar to what was observed in the BNCC, the NCTM also does not make explicit reference to the development of students' creativity. In this context, the question arises: could the development of skills such as reflection, argumentation and teamwork not, in parallel, contribute to the development of creativity?

Another significant advance in qualifying the teaching of Mathematics was observed in Portugal in the last decade. Based on an order from the State Secretariat for Education, a Mathematics Working Group (GTM) was created in 2018, whose mission was to prepare a set of recommendations on the teaching, learning and assessment of this subject. The group began its work by analyzing documents that addressed educational aspects over the last thirty years in Portugal.

Scientific research and national and foreign curricular documents (United States, Finland, Singapore and Estonia) were studied, as well as national reports on different plans and measures aimed at improving mathematical learning. Based on the analysis of this vast diversity of documents, the GTM prepared a preliminary report that included a set of 24 recommendations to be subject to public assessment at the end of 2019. At this stage, several entities and groups, including the Portuguese Association of Mathematics Teachers (APM), contributed opinions. Finally, at the beginning of 2020, the *Recomendações para a melhoria das aprendizagens dos alunos em Matemática* [Recommendations for improving student learning in Mathematics were published].

The final version of these recommendations was organized into four domains: the Mathematics curriculum, curriculum development dynamics, student performance assessment and teacher training, which “overall constitute an integrated whole” (Portugal, 2020, p. 292). According to the document, “the set of recommendations relating to the curriculum is fundamental in nature and the success of its implementation is reinforced by the recommendations of the other domains” (Portugal, 2020, p. 292). Table 1 presents a summary of the 22 recommendations that made up the final document.

Table 1: Summary of Recommendations indicated by the GTM

Domains	**Recommendations (R)**
The Mathematics curriculum	R1: a new, global and aligned Mathematics curriculum; R2: a Mathematics curriculum with two levels of decision-making; R3: a principles-driven Mathematics curriculum; R4: a Mathematics curriculum with diverse purposes for all students; R5: a Mathematics curriculum with relevant content and based on mathematical understanding; R6: a Mathematics curriculum with methodological guidelines focusing on students' mathematical experience; R7: a Mathematics curriculum with diverse and efficient resources; R8: a Mathematics curriculum that assumes the value of formative pedagogical assessment; R9: a Mathematics curriculum in Preschool Education; R10: a Mathematics curriculum for Basic Education; R11: a Mathematics curriculum for Secondary Education;

	R12: a Mathematics curriculum produced by teams with appropriate profiles.
Curriculum development dynamics	R13: nationally regulated curriculum change processes; R14: curriculum development with conditions in schools; R15: curriculum development supported by adequate resources.
Student performance assessment	R16: assessment practices in favour of success rather than retention; R17: external assessment tests aligned with the mathematical learning provided for in the national Mathematics curriculum; R18: comparable external assessment; R19: situated interpretation of the results of the assessment tests.
Teacher education	R20: sustainability for the initial training of educators and teachers; R21: need for efficient continuing education programs in Mathematics teaching; R22: unequivocal appreciation of the teaching profession.

Source: Own elaboration based in Portugal (2020)

Of the set of 22 recommendations, five of them (R3, R5, R6, R7 and R15) are directly related to the scope of this study, as they mention mathematical experiences and the use of materials suitable for teaching Mathematics. Of these, four are related to the curriculum domain, while the fifth is related to the dynamics of curriculum development.

In R3, when mentioning that the Mathematics curriculum must respect the principles of Universality, Internal Coherence, Relevance, Focus and High Cognitive Level, it is highlighted, regarding this last aspect, that “curriculum guidelines should require that students be subjects of mathematically rich and challenging learning experiences, which provide their respective mathematical reasoning and reflection on their learning” (Portugal, 2020, p. 304).

In the analysis of R5, the document emphasizes that a Mathematics curriculum must value understanding, a fundamental aspect for the success of mathematical learning for all students. It also explains that the curriculum should consider both mathematical knowledge and mathematical skills as content, to be addressed in an integrated manner. Thus, “problem solving, mathematical reasoning, communication, connections, the use of multiple representations, procedural fluency, creativity, digital literacy, reflection (metacognition), persistence/resilience and the ability to work individually and collaboratively must be considered in a balanced way” (Portugal, 2020, p. 295).

When addressing *A Mathematics curriculum with methodological guidelines focused on students’ mathematical experience*, R6 explicitly mentions what this study seeks to highlight for Brazilian mathematics educators. In addition to emphasizing the importance of curriculum clarifying aspects directly related to the approach to Mathematics and the role of the teacher and student, the recommendation highlights the need to diversify mathematical experiences.

According to the document (Portugal, 2020, p. 296), this diversification of mathematical experiences should be based on

> tasks of a diverse nature, as well as a classroom dynamic that involves the student, making it essential to frequently carry out exploratory teaching practices in Mathematics, which provide dialogic learning based on the collective discussion of students' mathematical productions, in which multiple mathematical representations are explored and connected.

In addition, R7 mentions that the Mathematics curriculum should consider not only technological tools as resources for teaching and learning Mathematics as a means of promoting the expansion of mathematical experience, but also include manipulative materials that promote the understanding of mathematical knowledge and the connection between different mathematical representations. In this sense, R15 explicitly highlights the need for, among the desirable resources, Mathematics Laboratories or a set of resources that can be used in the classroom, “that correspond to a minimum equipment compatible with the mathematical experiences to be provided” (Portugal, 2020, p. 301).

In summary, the report in question devotes a large part of its recommendations to methodological aspects related to practices of exploratory teaching of Mathematics and the importance of involving students in activities that promote the development of mathematical reasoning, communication, connections, creativity, as well as metacognition. It also adds to the need for this teaching to be supported by the use of diverse and efficient resources, whether technological tools or manipulable materials.

Focusing on South America, it is interesting to analyze some of the proposals for curricular modifications underway in Chile. For several decades, this country has been achieving significant results in terms of Mathematics learning in the South American continent.

After a period of implementing the previous Curriculum Bases and realizing the need to rethink the National Curriculum, the Chilean government structured a technical study process. This study required the incorporation of a diagnostic stage of the gradual implementation of the curriculum in force since 2012 to date, collecting evidence and lessons learned from the Curricular Prioritization undertaken in 2020, amid the social and health emergency experienced.

The update proposal was prepared based on documentary analyses and technical studies, combined with broad participatory processes and calls for the school community. The process was based on, in addition to monitoring and evaluation studies of previous curricula, comparative analysis with international curricula, as well as consultation with experts from different areas.

Thus, the Chilean Ministry of Education sought to develop a flexible curricular structure in schools and classrooms that, without sacrificing equity, would favor its contextualization in different realities, with proposals that would motivate teachers and students, contributing to the quality of learning and pedagogical innovation. As a result of this process, the Chilean Ministry of Education recently made available the document entitled *Bases Curriculares 1° Básico a 2° Medio: propuesta de actualización para consulta pública 2024* [Bases Curriculares 1° Básico a 2° Medio: propuesta de actualización for public consultation 2024].

The document begins by highlighting four fundamental purposes for the update: Curricular harmonization with a sense of educational path, Integration of learning, Disciplinary updating, and Pedagogical and Curriculum Management (Chile, 2024). Therefore, it indicates the importance of structuring a curricular design in which learning with a practical dimension prevails, rescuing the experiential sense and the interest in knowledge that is transferred to life.

The desirable protagonism of students in their learning and, in particular, in activities that involve play, investigation-experimentation, and dialogue, are also relevant aspects mentioned in the document. In line with these ideas, communication skills are also highlighted as one of the topics to be strengthened in this update.

However, it is in the *Cross-Cutting Learning Objectives* (CLO) that the proposal's major innovations can be seen. 13 CLOs are defined for Basic and Secondary Education (Chile, 2024), structured in the dimensions described in Table 2.

In the *Creativity* dimension, there is an intertwining with this study and with the other documents already studied. For this dimension, from 1st to 6th Basic, the CLO (Chile, 2024, p. 18) indicates that students are expected to be able to

> generate original and innovative ideas to respond creatively to personal or collective curiosity, interests and challenges of different kinds; incorporating exploration from diverse perspectives and knowledge, experimentation, investigation and evaluation, and demonstrating initiative and flexibility.

Table 2: Summary of the Cross-Cutting Learning Objectives indicated by MINEDUC

Well-being and health	Democracy, Human Rights and Memory	Critical Thinking
Socio-emotional well-being	Environmental Education	Collaboration
Affection and sexuality	Identity and Belonging	Creativity
Spiritual development	Digital Citizenship	
Community life and diversity	Communication	

Source: Own elaboration based in Chile (2024)

Related to the same dimension, but aimed at students from 7th grade to 2nd grade, the CLO advances by bringing elements such as divergent thinking, personal and collective knowledge and originality. As indicated in the document (Chile, 2024, p. 20), students are expected to be able to:

> generate creative ideas that respond to curiosity, interests and challenges of different types and areas, using divergent thinking, personal and collective experiences and knowledge, through research, analysis of options, planning, experimentation and evaluation, and demonstrating initiative, flexibility, originality and innovation.

Therefore, it is recommended that pedagogical practices be aimed at fostering original and innovative ideas that open space for creativity and curiosity. Additionally, these practices are expected to address a variety of perspectives and knowledge through experimentation, investigation, and evaluation.

Furthermore, when dealing with the approaches of the Mathematics area, it recalls these guidelines, explaining that the discipline will have as its motto to emphasize the relationship between mathematical knowledge, the development of mathematical thinking skills, and their application to solve problems and model phenomena or situations of everyday and social life (Chile, 2024). It also notes that the curricular approach adapts to the socio-historical-cultural context, which implies understanding mathematical knowledge through its construction and application, considering human development as intrinsically social.

According to the document, the socio-historical-cultural approach to mathematics emphasizes that its concepts and procedures are culturally constructed by human beings throughout history. The CLO (Chile, 2024, p. 55) further warns that

> doing mathematics does not consist only of using calculation procedures to provide answers to proposed problems using a repertoire of proven techniques. On the contrary, it is a science that invites us to explore, experiment, play, and make mistakes, which requires autonomy, creativity, and collaboration in the search for solutions.

In other words, Mathematics is not a fixed and immutable set of knowledge, facts and procedures external to human practice that must simply be learned. Doing mathematics involves exploring, experimenting and dealing with mistakes, building learning from moments of reflection and metacognition.

It is thus assumed that the essence of mathematical activity must be carried out collaboratively, considering the intra-mathematical, everyday and social contexts that give meaning to mathematical knowledge. Consequently, "students are expected to be able to express strategies and ways of thinking through communication and mathematical argumentation" (Chile, 2024, p. 55).

After a detailed analysis of the set of selected documents, it is possible to observe that all of them recommend guidelines that emphasize teaching Mathematics based on mathematical experiences and experimental practices. They emphasize that teaching and learning practices in Mathematics must go beyond simple problem-solving, prioritizing procedures that favor the development of creative reasoning, communication and the construction of connections between mathematical knowledge.

Furthermore, the documents agree to highlight the importance of using mathematical and technological tools as essential resources for students to construct their own meanings for mathematical ideas, reason creatively and express their mathematical thinking.

5 Mathematical creativity depends on experimentation

If the goal is to truly develop mathematical creativity, it is necessary to adopt pedagogical practices that prioritize reasoning over repetition and memorization. To do this, it is essential to adequately support the teacher's pedagogical practice, encouraging and guiding the use of games or manipulative materials.

This involves reaffirming the importance of these teaching resources, highlighting that the student must be the protagonist of his or her own learning, but with adequate methodological support. It is about putting experimentation at the service of argumentation, creativity, engagement and metacognition, with the aim of promoting active and participatory learning.

As mathematics educators, it is essential to understand that traditional pedagogical practices, based on repetition and memorization activities, contribute little or nothing to the development of students' mathematical creativity. On the other hand, activities that encourage students to explore, investigate, infer, reflect, analyze, compare, question, present, among others, open up space for the expression of their genuine and creative thinking.

In this context, it was relevant to analyze the selected documents, even though most of them did not explicitly address the relationship between mathematical experimentation and the development of creativity. Based on this data, we can see the possibility that the adoption of practices that encourage students to reflect, as suggested by the BNCC, contributes, as a consequence, to the development of creativity.

Activities that promote student reflection are deeply connected to those that stimulate creativity, since both involve cognitive processes that encourage students to question, explore and develop new ways of thinking. Reflection allows students to critically analyze their ideas and better understand what they are learning.

This process challenges them not only to accept ready-made answers, but to consider different perspectives and alternatives, which creates an environment that is favorable to creativity. By reflecting on their experiences and the concept they are studying, students are encouraged to generate more original solutions and develop new approaches to solving problems.

In addition, reflection is a central component of critical thinking that is directly linked to creativity. When students reflect on a problem or situation, they need to analyze different possibilities and think flexibly, which increases their ability to create innovative solutions. This means that reflection not only helps students to better understand concepts, but also to make connections between seemingly distant ideas — a fundamental aspect in the development of creativity.

By stimulating metacognition — that is, thinking about one's own thinking — reflection also helps students become more aware of their learning processes. This awareness allows them to adjust their approaches and explore new strategies, which in turn fosters creative potential. In an environment where reflection is encouraged, students feel more confident about experimenting and making mistakes, which increases their possibilities for thinking originally and finding unconventional ways to solve problems.

Therefore, activities that promote reflection help students develop metacognition and the ability to critically analyze their own ideas, which creates fertile ground for creative exploration. Both approaches, reflection and creativity, are intertwined in the process of active exploration, questioning and problem-solving, fostering the development of a creative mindset that is essential to ensuring everyone's mathematical learning.

6 In closing

The conclusions of this study reinforce that the centrality of the student in the learning process is essential for promoting meaningful Mathematics teaching, capable of fostering creativity, critical thinking and the active construction of knowledge. Traditional practice, centered on the transmission of ready-made definitions and formulas, tends to inhibit engagement, comparable to the loss of interest caused by spoilers in a movie. On the other hand, strategies that encourage the exploration of different approaches, the formulation of hypotheses and the appreciation of error as part of the creative learning process are fundamental.

According to Martinez (1995, 2008), creativity is not a privilege of a few, but a potential of all students, which can be developed through educational environments that favor investigation and originality. Thus, it becomes imperative to reflect on how guiding documents, such as the BNCC, can help in the integration of experimental activities that enhance creativity in Mathematics teaching.

It can therefore be stated that teaching Mathematics means providing students with opportunities to experience the essence of mathematical activity as a dynamic and collaborative process, based on experimentation, reflection and dialogue. This approach requires the creation of learning environments that connect Mathematics to everyday, social and intra-mathematical contexts, allowing students to develop skills such as communication and mathematical argumentation, in accordance with the objectives expressed in the documents analyzed.

The integration of technological tools and experimental practices reinforces this purpose, by encouraging the construction of one's own meanings, creative reasoning and the ability to establish connections, showing that Mathematics, far from being static, is a living field, continually constructed and reconstructed by human interaction.

It can therefore be concluded that experimentation plays a central role in the development of mathematical creativity, by enabling students to be protagonists of their learning in an environment that values reasoning and investigation. Unlike practices based on memorization and repetition, activities that promote exploration, reflection, and critical analysis allow students to construct their own meanings and establish deep connections between mathematical concepts and their experiences.

In this process, reflection and metacognition are essential elements, favoring not only the understanding of concepts, but also the ability to think creatively, propose original solutions, and adapt to new situations. Thus, promoting pedagogical practices that integrate experimentation and reflection is a promising path to transform the teaching of Mathematics, promoting active and creative learning, aligned with contemporary educational objectives.

References

BRASIL. Ministério da Educação. Secretaria de Educação Básica. *Base Nacional Comum Curricular*: Educação Infantil e Ensino Fundamental. Brasília: MEC/SEB, 2017.

CAMACHO, Mariana Sofia Fernandes Pereira. *Materiais manipuláveis no processo ensino/aprendizagem da Matemática:* aprender explorando e construindo. 2012. 102f. Dissertação (Mestrado em Ensino da Matemática). Universidade da Madeira. Madeira.

CELLARD, André. A análise documental. *In*: POUPART, Jean; DESLAURIERS, Jean-Pierre; GROULX, Lionel-H; LAPERRIÈRE, Anne; MAYER, Robert; PIRES, Alvaro P. (Org). *A pesquisa qualitativa*: enfoques epistemológicos e metodológicos. Tradução de Ana Cristina Arantes Nasser. Petrópolis: Vozes, 2008, p. 295-316.

CHILE. Ministerio de Educacíon. *Bases Curriculares 1° Básico a 2° Medio*: propuesta de actualización para consulta pública 2024. Santiago: Mineduc, 2024.

ESTEBAN, Maria Paz Sandín. *Investigación cualitativa en Educación*: fundamentos y tradiciones. Madri: McGraw-Hill, 2010.

FONSECA, João José Saraiva. *Metodologia da pesquisa científica*. Fortaleza: UECE, 2002.

JELINEK, Karin Ritter. *Jogos nas aulas de Matemática*: brincadeira ou aprendizagem? O que pensam os professores? 2005. 147f. Dissertação (Mestrado em Ciências e Matemática). Pontifícia Universidade Católica do Rio Grande do Sul. Porto Alegre.

LORENZATO, Sérgio (Org.). *O Laboratório de Ensino de Matemática na formação de professores*. Campinas: Autores Associados, 2012.

LORENZATO, Sérgio. *Para aprender Matemática*. Campinas: Autores Associados, 2008.

MARTÍNEZ, Albertina Mitjáns. A criatividade na escola: três direções de trabalho. *Linhas Críticas*, v. 8, n. 15, p. 189-206, 2002. https://doi.org/10.26512/lc.v8i15.3057

MARTÍNEZ, Albertina Mitjáns. *Criatividade e personalidade*: implicações educativas. Campinas: Papirus, 1995.

MARTÍNEZ, Albertina Mitjáns. *Criatividade, personalidade e Educação*. Brasília: Editora UnB, 2008.

MATOS, José Manoel; SERRAZINA, Maria de Lurdes. *Didática da Matemática*. Lisboa: Universidade Aberta, 1996.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *Principles and Standards*. Reston: NCTM, 2000.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *Principles to actions*: ensuring Mathematical success for all. Reston: NCTM, 2014.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS. *Professional teaching* *standards*. Reston: NCTM, 1991.

PAIS, Luis Carlos. Intuição, experiência e teoria geométrica. *Zetetike*, v. 4, n. 2, p. 65-74, 1996.

PORTUGAL. Ministério da Educação. Grupo de Trabalho de Matemática. *Recomendações para a melhoria das aprendizagens dos alunos em Matemática*. Lisboa: ME/GTM, 2020.