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ACTIVE LEARNING METHODOLOGIES IN PRE-SERVICE PRIMARY TEACHER EDUCATION FOR MATHEMATICS: AN ANALYSIS OF BNCC-ALIGNED LESSON PLANS AND PRACTICES

METODOLOGIAS ATIVAS NA FORMAÇÃO INICIAL DE PEDAGOGOS PARA O ENSINO DE MATEMÁTICA: ANÁLISE DE PLANOS E PRÁTICAS ALINHADOS À BNCC

METODOLOGÍAS ACTIVAS EN LA FORMACIÓN INICIAL DE PEDAGOGOS PARA LA ENSEÑANZA DE LAS MATEMÁTICAS: ANÁLISIS DE PLANES Y PRÁCTICAS ALINEADOS CON LA BNCC

Flaviane Melo de Anchieta
Mestre em Diversidade e Inclusão, Universidade Federal Fluminense, Niterói
E-mail: pesquisas.flaviane@gmail.com | ORCID: 0000-0002-6665-0765

Marcus Vinicius Gomes de Oliveira
Mestre em Educação, Universidade Federal Rural do Rio de Janeiro, Seropédica
E-mail: farma.vinicius@gmail.com | ORCID: 0000-0002-8991-8947

Jaqueline Pereira de Azeredo Rapagnã
Especialista em Educação Infantil, Universidade Federal Fluminense, Niterói
E-mail: jrapagna@id.uff.br | ORCID: 0009-0000-7828-1373

Laís Lemos Silva Novo Pinheiro
Doutora em Educação, Universidade do Estado do Rio de Janeiro, Rio de Janeiro
E-mail: laislemosnovo@hotmail.com | ORCID: 0000-0002-9210-0484

Juliana de Oliveira Lima Vianna
Doutora em Letras, Universidade do Estado do Rio de Janeiro, Rio de Janeiro
E-mail: juolvianna@gmail.com | ORCID: 0009-0002-8301-4397

Luana Regina Ramos Caldeira Mata
Mestre em Psicologia, Universidade Salgado de Oliveira, Niterói
E-mail: luanareginaramos@gmail.com | ORCID: 0009-0008-5252-8161

Rafael Rossi de Sousa
Mestre em Psicologia, Universidade de Vassouras, Saquarema
E-mail: rafael.sousa@univassouras.edu.br | ORCID: 0000-0003-1369-6871

Luciano Carvalho Rapagnã
Doutor em Biologia Marinha e Ambientes Costeiros, Universidade Federal Fluminense, Niterói
E-mail: lucianorapagna@id.uff.br | ORCID: 0000-0002-9009-4463

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Abstract

Mathematics teaching in the early years of Brazilian elementary school is still characterized by transmissive practices and the repetition of algorithms, which are associated with low achievement and negative attitudes toward the subject. Pre-service education of pedagogy students, who will be responsible for this teaching, is a strategic space to break this cycle. This study analyzed how active learning methodologies were mobilized by pre-service teachers when planning and enacting, through peer simulations, mathematics activities aligned with the Brazilian National Common Curricular Base (BNCC). This is a qualitative, descriptive-interpretive study conducted in the course Mathematics Teaching Methodology II of a Pedagogy program. The corpus comprised 11 lesson plans produced by two groups of pre-service teachers, observation records, student productions, and reflective reports. Lesson plans underwent documentary analysis, with coding of eight elements of active methodologies and descriptive statistics; three interventions (multiplication board game, mathematical market, and challenge wheel) were examined in depth through categorical-thematic content analysis. The plans covered all five BNCC thematic units, mainly Numbers and Algebra (27.3% each), and included on average 4.7 (SD = 1.1) of the eight elements analyzed. Playfulness (90.9%), collaborative work, and concrete materials (72.7% each) were the most frequent; planned oral argumentation and digital technology were the least frequent (27.3% each). Content analysis yielded four categories: engagement and participation, logical-mathematical reasoning, collaborative learning, and pedagogical mediation. The activities fostered participation, the use of diverse strategies, such as numerical decomposition and comparison of quantities, and the collective validation of solutions, especially when the teacher educator asked participants to explain their reasoning. Active methodologies in pre-service education broaden future teachers' didactic repertoire, provided they are combined with intentional planning of mathematical argumentation and skilled teacher mediation.

Keywords: Mathematics education; Active learning; Pre-service teacher education; Mathematical games; BNCC.

Resumo

O ensino de Matemática nos anos iniciais do Ensino Fundamental ainda é marcado por práticas transmissivas e pela repetição de algoritmos, o que se associa a baixo desempenho e a atitudes negativas em relação à disciplina. A formação inicial do pedagogo, responsável por esse ensino, constitui espaço estratégico para romper esse ciclo. Este estudo analisou como metodologias ativas foram mobilizadas por licenciandas de Pedagogia no planejamento e na vivência, em simulação didática, de atividades de Matemática alinhadas à Base Nacional Comum Curricular (BNCC). Trata-se de pesquisa qualitativa, descritivo-interpretativa, desenvolvida na disciplina Metodologia do Ensino da Matemática II de um curso de Pedagogia. O corpus reuniu 11 planos de aula produzidos por dois grupos de licenciandas, registros de observação, produções e relatórios reflexivos. Os planos foram submetidos a análise documental, com codificação de oito elementos de metodologias ativas e estatística descritiva; três intervenções (jogo de tabuleiro da multiplicação, mercadinho matemático e roleta do desafio) foram examinadas em profundidade por análise de conteúdo categorial-temática. Os planos contemplaram as cinco unidades temáticas da BNCC, com predomínio de Números e Álgebra (27,3% cada), e apresentaram em média 4,7 (DP = 1,1) dos oito elementos analisados. Ludicidade (90,9%), trabalho colaborativo e material concreto (72,7% cada) foram os mais frequentes; argumentação oral prevista e tecnologia digital, os menos frequentes (27,3% cada). A análise de conteúdo originou quatro categorias: engajamento e participação, raciocínio lógico-matemático, aprendizagem colaborativa e mediação pedagógica. As atividades favoreceram a participação, a mobilização de estratégias diversificadas, como decomposição numérica e comparação de grandezas, e a validação coletiva de soluções, sobretudo quando a docente solicitou a explicitação dos raciocínios. Conclui-se que metodologias ativas na formação inicial ampliam o repertório didático dos futuros professores, desde que acompanhadas de planejamento intencional da argumentação matemática e de mediação docente qualificada.

Palavras-chave: Educação matemática; Metodologias ativas; Formação inicial de professores; Jogos matemáticos; BNCC.

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Resumen

La enseñanza de las Matemáticas en los primeros años de la Educación Primaria brasileña sigue marcada por prácticas transmisivas y por la repetición de algoritmos, lo que se asocia a bajo rendimiento y a actitudes negativas hacia la asignatura. La formación inicial del pedagogo es un espacio estratégico para romper ese ciclo. Este estudio analizó cómo las metodologías activas fueron movilizadas por futuras maestras al planificar y simular entre pares actividades de Matemáticas alineadas con la Base Nacional Común Curricular (BNCC). Es una investigación cualitativa, descriptivo-interpretativa, desarrollada en la asignatura Metodología de la Enseñanza de las Matemáticas II de una carrera de Pedagogía. El corpus reunió 11 planes de clase elaborados por dos grupos de estudiantes, registros de observación, producciones e informes reflexivos. Los planes se sometieron a análisis documental, con codificación de ocho elementos de metodologías activas y estadística descriptiva; tres intervenciones (tablero de la multiplicación, mercadito matemático y ruleta del desafío) se examinaron en profundidad mediante análisis de contenido categorial-temático. Los planes abarcaron las cinco unidades temáticas de la BNCC, con predominio de Números y Álgebra (27,3% cada una), e incluyeron en promedio 4,7 (DE = 1,1) de los ocho elementos. Lo lúdico (90,9%), el trabajo colaborativo y el material concreto (72,7% cada uno) fueron los más frecuentes; la argumentación oral prevista y la tecnología digital, los menos frecuentes (27,3% cada uno). El análisis originó cuatro categorías: compromiso y participación, razonamiento lógico-matemático, aprendizaje colaborativo y mediación pedagógica. Las actividades favorecieron la participación, el uso de estrategias diversificadas y la validación colectiva de soluciones, sobre todo cuando la docente solicitó la explicitación de los razonamientos. Las metodologías activas en la formación inicial amplían el repertorio didáctico de los futuros docentes, siempre que se acompañen de una planificación intencional de la argumentación matemática y de una mediación docente cualificada.

Palabras clave: Educación matemática; Metodologías activas; Formación inicial docente; Juegos matemáticos; BNCC.

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1. Introduction

Mathematics plays a central role in children's intellectual development, especially in the early years of elementary school, when the foundations of logical thinking, problem solving, and understanding of the quantitative relationships present in everyday life are established. At this stage, mathematical proficiency involves not only procedural fluency but also conceptual understanding, strategic competence, adaptive reasoning, and a productive disposition toward the subject (National Research Council).

Learning indicators, however, reveal a worrying picture. In the 2022 Programme for International Student Assessment (PISA), only about 27% of Brazilian 15-year-olds reached proficiency Level 2 in mathematics, considered the minimum threshold for full participation in society (OECD, *PISA 2022*). International and national assessments associate this performance, among other factors, with teaching practices centered on content transmission and the repetition of algorithms (Mullis and Kelly; OECD, *PISA 2018*; Hiebert and Grouws).

In this model, students take a predominantly passive role and are asked to memorize rules and apply procedures without understanding the principles that underpin them. Mathematics comes to be perceived as abstract and distant from reality, and is often associated with insecurity and anxiety (Schoenfeld; Boaler). Mathematics anxiety, in turn, consumes working-memory resources and impairs performance, feeding a cycle of avoidance and low self-confidence (Ashcraft and Krause; Dowker et al.).

As an alternative, active learning methodologies propose that students learn by doing, reflecting, and interacting with peers, while the teacher acts as a mediator of intentionally organized didactic situations (Bonwell and Eison; Prince). A meta-analysis of 225 studies in science, engineering, and mathematics showed that active learning increased performance and reduced failure rates compared with traditional lecturing (Freeman et al.). In the Brazilian context, reviews indicate that these approaches stimulate reflection and problem solving in mathematics (Bossi and Schimiguel; Lima et al.).

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Transforming these practices depends largely on the pre-service education of pedagogy graduates, the generalist teachers responsible for mathematics in the early years. Studies show that these teachers often complete their degree with gaps in content knowledge, pedagogical content knowledge, and curricular knowledge, which hinders the implementation of the National Common Curricular Base (BNCC) (Pertile and Justo; Santos). Formative experiences that allow pre-service teachers to plan, enact, and reflect on active practices are therefore a promising path, yet one that remains poorly documented empirically in Brazil, particularly regarding a systematic description of the plans produced and the interactions that emerge from them.

In light of this gap, this study aimed to analyze how active learning methodologies were mobilized by pre-service pedagogy teachers when planning and enacting BNCC-aligned mathematics activities. Specifically, it sought to: (i) characterize the lesson plans produced in terms of thematic units, teaching resources, and the elements of active methodologies they included; and (ii) understand how activities based on games, contextualized situations, and collaborative problem solving fostered engagement, mathematical reasoning, collaboration, and pedagogical mediation.

2. Literature Review

2.1 Active learning methodologies and their theoretical foundations

Active learning methodologies encompass strategies that engage students in activities requiring them to think about what they are doing, such as discussing, solving problems, making decisions, and producing explanations (Bonwell and Eison). Their empirical basis is consistent: in addition to gains in achievement (Freeman et al.; Prince), inquiry-based approaches in mathematics foster more positive attitudes and reduce inequalities in participation (Laursen and Rasmussen). Implementation, however, may meet student resistance when the proposal is not well explained and mediated by the teacher (Blackmon et al.).

Theoretically, these approaches draw on the theory of meaningful learning, according to which new knowledge is learned more stably when anchored in the learner's prior knowledge (Ausubel et al.), and on the cultural-historical perspective,

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which conceives development as a process mediated by language and social interaction, especially within the zone of proximal development (Vygotsky). From this perspective, teacher mediation is not incidental: it is what turns interaction into a learning opportunity (Farias and Bortolanza). Approaches such as Realistic Mathematics Education, which start from contextualized situations, show substantial positive effects on mathematics learning (Juandi et al.).

2.2 Games and manipulatives in mathematics teaching

Among active strategies, mathematical games and manipulatives hold a prominent place in the early years. In a survey of 248 Australian teachers, almost all reported using games at least once a week to introduce concepts, consolidate knowledge, and develop fluency, and considered them effective for engagement and for developing understanding, reasoning, and problem solving (Russo et al., “How Primary Teachers”). Systematic and integrative reviews confirm the benefits of non-digital and digital games for motivation, logical reasoning, autonomy, and social relationships (Russo et al., “Non-Digital Games”; Brandão et al.; Rangel and Rangel), and experimental studies show gains when the game is integrated with explicit learning goals (Bragg).

Manipulatives, in turn, support the transition between concrete, pictorial, and symbolic representations (Moyer-Packenham and Westenskow). Lemes, Cristovão, and Grando emphasize, however, that the potential of these resources is realized only through planning, intentionality, and productive teacher interventions during the activity. Games should not be treated as mere pastimes, but as mediated situations of mathematical inquiry (Moreira; Andrade; Kieckhoefel and Pereira). In digital and gamified games, elements such as levels, scores, and rewards can increase engagement (Pan et al.; Alves et al.; Rodrigues and Silva), but excessive emphasis on speed and ranking may reinforce anxiety and shift the focus from understanding to quick correct answers (Boaler).

2.3 Pre-service education of pedagogy teachers and the BNCC

The BNCC organizes elementary school mathematics into five thematic units (Numbers, Algebra, Geometry, Quantities and measurement, and Probability and statistics) and emphasizes mathematical literacy, understood as the ability to reason,

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represent, communicate, and argue mathematically (Brasil, *Base Nacional*). The document values solving and posing problems, using different strategies and representations, and communicating procedures (Ortega; Santana). Its implementation in the early years, however, depends on teachers who master both the objects of knowledge and the ways of teaching them (Santos; Pertile and Justo).

This body of knowledge corresponds to what Shulman called pedagogical content knowledge and what Ball, Thames, and Phelps detailed as mathematical knowledge for teaching. To develop it, the literature on teacher education recommends "approximations of practice," situations in which pre-service teachers plan, rehearse, and analyze teaching episodes in a formative setting (Grossman et al.). Experiences of this kind, articulated with the BNCC and with diversified teaching resources, have been reported as powerful for pre-service education (Barbosa and Maltempi; Lubachewski and Cerutti; Terçariol and Afecto), although they still lack a systematic description of the plans produced and the interactions observed, a gap this study seeks to address.

3. Methodology

3.1 Design and context

This is a qualitative, descriptive-interpretive study, designed as a case study of formative practice with retrospective analysis of pedagogical records, reported according to the *Standards for Reporting Qualitative Research* (O'Brien et al.). This approach is justified by the need to understand complex educational processes, such as participation, interactions, and the strategies mobilized in problem solving, which cannot be reduced to the measurement of outcomes. In addition, descriptive statistics were used to characterize the documentary corpus, without inferential purposes.

The study was conducted in the course Mathematics Teaching Methodology II, offered in the 4th semester of a Pedagogy program at a private higher education institution in the state of Rio de Janeiro, Brazil, in the first semester of 2025. Throughout the course, the pre-service teachers, organized in groups, planned mathematics activities for the 3rd and 4th grades of elementary school, made the teaching resources, and enacted the activities as teaching simulations (microteaching) among

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themselves in the university classroom, mediated by the course instructor. The activities were not implemented with children. Simulation is an approximation of practice in which pre-service teachers rehearse and analyze teaching episodes in a formative setting before facing the complexity of the school classroom (Grossman et al.).

3.2 Participants and corpus

Two groups of pre-service teachers from different 4th-semester classes took part: Group 1 (G1; n = 8) and Group 2 (G2; n = 7), totaling 15 participants. The corpus consisted of: (i) 11 lesson plans prepared by the groups (seven from G1 and four from G2); (ii) observation records produced during the classes; (iii) productions developed throughout the interventions, including the resources made; and (iv) reflective reports on the implementation of the activities. All plans stated at least one BNCC skill. The characterization of the plans is presented in Table 1.

Table 1 – Characterization of the lesson plans in the documentary corpus (n = 11)

Plan	Activity	Group / grade	BNCC skill	Thematic unit	Predominant resource	No. of elem.*
P1	Multiplication board game	G1 / 3rd	EF03MA07	Numbers	Analog game	6
P2	Mathematical market	G1 / 3rd	EF03MA20	Quantities and measurement	Contextualized simulation	6
P3	Fraction box	G1 / 3rd	EF03MA09	Numbers	Manipulative material	5
P4	Probability wheel	G1 / 3rd	EF03MA25	Probability and statistics	Analog game	5
P5	Inverse-operations explorer	G1 / 4th	EF04MA13	Algebra	Digital game	5
P6	Magic operations	G1 / 4th	EF04MA14	Algebra	Digital game	3
P7	Hunt for the unknown number	G1 / 4th	EF04MA15	Algebra	Digital game	3
P8	Challenge wheel	G2 / 3rd	EF03MA07	Numbers	Analog game	6
P9	Geometric memory game	G2 / 3rd	EF03MA15	Geometry	Analog game	4
P10	Analog and digital clock	G2 / 3rd	EF03MA23	Quantities and measurement	Manipulative material	4
P11	Preference table and chart	G2 / 3rd	EF03MA27	Probability and statistics	Data inquiry	5
	Summary	**3rd: 8 (72.7%)**	**8 skills**	**5 units**	**Games: 7 (63.6%)**	**4.7 (1.1)**

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Plan	Activity	Group / grade	BNCC skill	Thematic unit	Predominant resource	No. of elem.*
		4th: 3 (27.3%)				

Source: prepared by the authors (2026).
Note: * Number of active-methodology elements included in the plan, out of the eight analyzed (see Figure 3); in the summary row, mean (standard deviation). G1 = Group 1; G2 = Group 2. In P3, the plan assigned the activity to the Algebra unit; the official BNCC classification is adopted here.

Table 1 shows that the corpus covered all five BNCC thematic units and eight different skills, with a predominance of plans for the 3rd grade (8 of 11). Of the 11 plans, three interventions were selected for in-depth analysis because they had the richest observation records and represented distinct modalities of active methodology: the multiplication board game (P1), the mathematical market (P2), and the challenge wheel (P8). Chart 1 summarizes their alignment with the BNCC, and Figure 1 shows the resources produced.

Chart 1 – Interventions analyzed in depth and their alignment with the BNCC

Intervention	Learning objective	BNCC skill (thematic unit)	Competencies mobilized
I1 – Multiplication board game (P1)	Develop multiplicative reasoning and mental calculation strategies	EF03MA07 – solve and pose multiplication problems with the meanings of repeated addition and rectangular arrays, using different calculation strategies and representations (Numbers)	Logical reasoning, calculation flexibility, strategic thinking
I2 – Mathematical market (P2)	Estimate, measure, and compare mass and capacity in consumer situations	EF03MA20 – estimate and measure capacity and mass using non-standard and standard units, recognizing them on labels and packaging (Quantities and measurement)	Modeling real situations, decision-making, interpreting information
I3 – Challenge wheel (P8)	Solve varied problems through collaborative strategies	EF03MA07 – solve multiplication problems using different strategies; connects notions of parity, doubles, and halves (Numbers)	Mathematical argumentation, critical thinking, collaborative learning

Source: prepared by the authors (2026), based on Brasil (*Base Nacional*).

As shown in Chart 1, the three interventions address complementary thematic units and competencies: multiplicative calculation, measuring and comparing quantities in a consumer context, and collaborative solving of varied problems. This diversity made it possible to examine how different activity formats foster different dimensions of mathematics learning.

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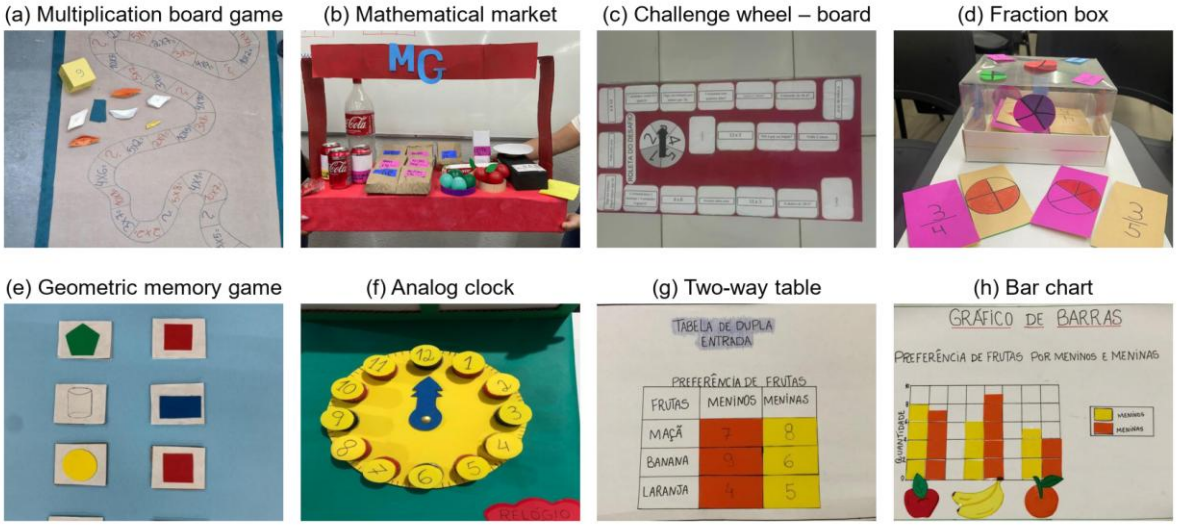
Figure 1 – Teaching resources made by the pre-service teachers



Source: authors' collection (2026). Panels (a), (b), and (c): interventions analyzed in depth (I1, I2, and I3).

Figure 1 highlights the predominance of resources made from low-cost materials (cardboard, EVA foam, bottle caps, and reused packaging), a relevant feature for transferring these practices to public schools. The photographs were selected so as not to show any identifiable people.

3.3 Analytical procedures

The analysis was conducted in two articulated stages. In the first, documentary stage, the 11 plans were coded by BNCC skill and thematic unit, grade, predominant teaching resource, and the presence (1) or absence (0) of eight elements characteristic of active methodologies, defined a priori from the literature: playfulness/game; collaborative work; competition/scoring; everyday contextualization; concrete materials; digital technology; inquiry, estimation, or multiple strategies; and planned oral argumentation (Bonwell and Eison; Lemes et al.; Brasil, *Base Nacional*). An element was considered present when it was explicitly included in the plan's development, resources, or expected outcomes. Results were summarized as absolute and relative frequencies, mean, standard deviation (SD), and range, computed in Python 3.12 (pandas and matplotlib libraries). The coding matrix and the script are available as supplementary material.

In the second stage, the records of the three selected interventions underwent categorical-thematic content analysis (Bardin) in three phases: (a) pre-analysis, with

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floating reading of the corpus and definition of the recording units (excerpts of observations, utterances, and productions with complete meaning); (b) exploration of the material, with coding and grouping of units into subcategories and categories; and (c) treatment of results and interpretation, articulating the categories with the literature. Categories emerged from the material, guided by the study's objectives. Coding was carried out by the authors; recording units and categories were discussed in team meetings, and interpretive disagreements were resolved by consensus, returning to the original records whenever necessary.

3.4 Trustworthiness and ethical considerations

Trustworthiness was pursued through source triangulation (plans, observations, productions, and reports), thick description of the interventions, maintenance of an audit trail (coding matrix and organized records), and discussion of interpretations among the researchers, following the criteria of credibility, transferability, and confirmability (Lincoln and Guba). We acknowledge that the course instructor is a member of the research team, which required reflexive attention to the dual role of teacher educator and researcher.

Regarding ethics, the study consists of a retrospective analysis of records produced during regular undergraduate teaching activities, without a prior research purpose, and of the theoretical deepening of situations that emerged from professional teaching practice, without disclosing data that could identify the participants. It therefore falls under the cases listed in the sole paragraph of Article 1 of Resolution No. 510/2016 of the Brazilian National Health Council (items VII and VIII), which waive registration and review by the CEP/Conep research ethics system (Brasil, *Resolução*). No children took part, and no personal or sensitive data were collected. The pre-service teachers' names were omitted, quoted utterances are identified only by the intervention to which they refer, and the published photographs show only the teaching materials, without people. Participants signed an institutional image-use authorization form.

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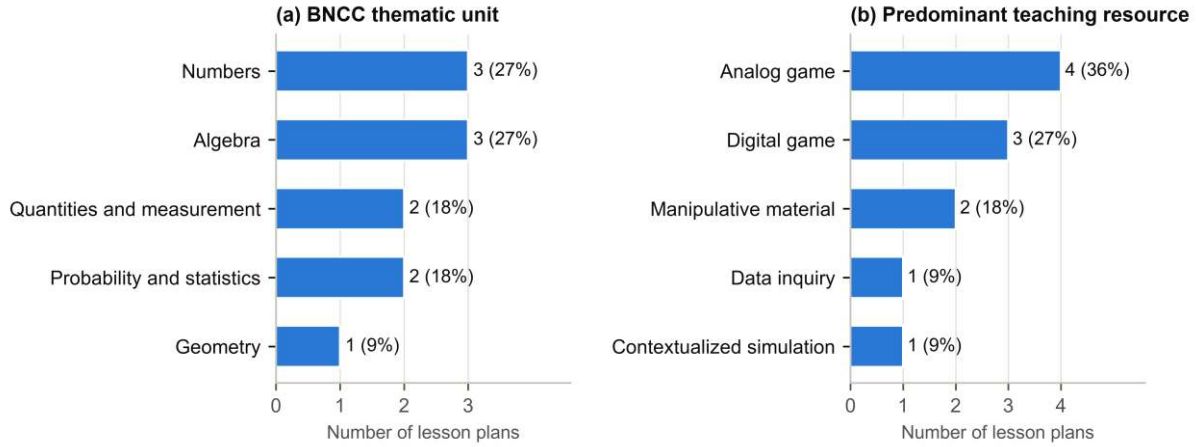
4. Results and Discussion

4.1 Characterization of the lesson plans

Figure 2 shows the distribution of the 11 plans by BNCC thematic unit and by predominant teaching resource.

Figure 2 – Distribution of lesson plans (n = 11) by BNCC thematic unit and predominant teaching resource



Source: prepared by the authors (2026). Values: number of plans (percentage).

As shown in Figure 2a, Numbers and Algebra accounted for 6 of the 11 plans (54.5%), followed by Quantities and measurement and Probability and statistics (two plans each) and Geometry (one plan). All Algebra plans were intended for the 4th grade and addressed inverse relationships between operations and the notion of equality (EF04MA13 to EF04MA15). Regarding resources (Figure 2b), analog games (36.4%) and digital games (27.3%) predominated, followed by manipulative materials (18.2%). This profile is consistent with the literature, which identifies games as the most widely used active resource in the early years (Russo et al., “How Primary Teachers”; Brandão et al.).

A finding relevant to teacher education concerns curricular classification. The fraction box plan (P3) was labeled by the pre-service teachers as belonging to the Algebra unit, although the skill indicated (EF03MA09, which associates the quotient of divisions with the ideas of half, third, fourth, fifth, and tenth parts) belongs to the Numbers unit. This inaccuracy suggests weaknesses in curricular knowledge, a dimension of professional knowledge already identified as a gap in the education of

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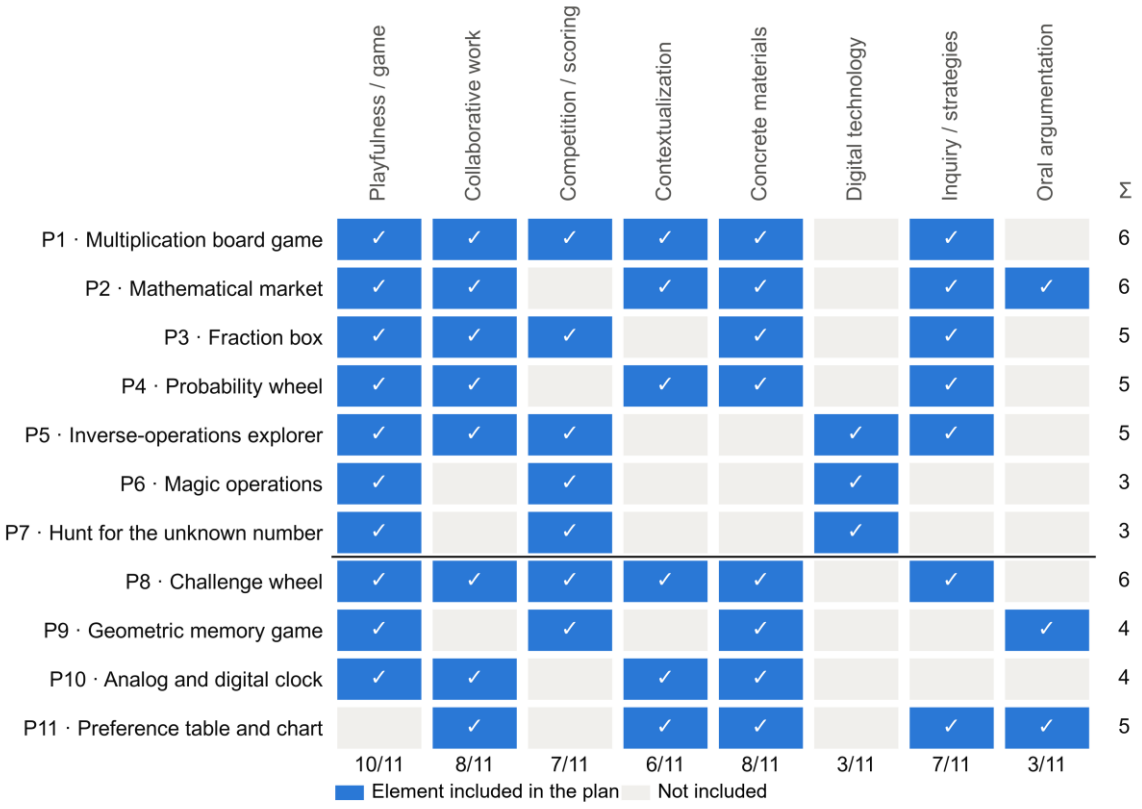
early-years teachers (Pertile and Justo; Ball et al.), and points to the value of formative activities that make the organization of the BNCC explicit.

Figure 3 details the presence of the eight elements of active methodologies in each plan.

Figure 3 – Active-methodology elements included in each lesson plan



Source: prepared by the authors (2026). The horizontal line separates G1 and G2 plans; Σ = number of elements per plan; values at the bottom show the frequency of each element.

On average, the plans included 4.7 (SD = 1.1; range 3 to 6) of the eight elements analyzed (Figure 3). Playfulness was present in 10 plans (90.9%), followed by collaborative work and concrete materials (8 plans each; 72.7%), competition/scoring and inquiry or multiple strategies (7 plans each; 63.6%), and everyday contextualization (6 plans; 54.5%). The least frequent elements were digital technology and planned oral argumentation (3 plans each; 27.3%).

Two patterns stand out. The first concerns the digital games (P5 to P7), which included on average 3.7 elements, compared with 5.1 in the other plans. Two of them (P6 and P7) were structured around time, scores, and individual ranking, with no

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provision for collaboration or discussion of strategies. This design favors quick correct answers, which may intensify mathematics anxiety and restrict conceptual understanding (Boaler; Ashcraft and Krause), and shows that simply incorporating technology does not guarantee an active approach (Ventura and Gomes). The second pattern concerns oral argumentation: although central to the mathematical literacy advocated by the BNCC, it was explicitly planned in only three plans (P2, P9, and P11). As shown below, argumentation frequently emerged during the interventions, but mainly in response to the instructor's prompts rather than from the pre-service teachers' planning.

4.2 Categories emerging from content analysis

Content analysis of the three selected interventions yielded four categories and nine subcategories, summarized in Chart 2.

Chart 2 – Categories, subcategories, and empirical evidence from the content analysis

Category	Subcategory	Empirical evidence observed	Interventions	Data source
Engagement and participation	Active participation in activities	Interest in understanding the rules and taking part in solving the challenges	I1, I2, I3	Observation
	Sustained interest	Continuous involvement during games and challenges, with participation in group discussions	I1, I2, I3	Observation; reflective report
Logical-mathematical reasoning	Numerical decomposition and additive reasoning	“four times six is twenty-four, so four times twelve is double”	I1	Observation; production
	Comparison of quantities	“this one looks cheaper, but it has fewer grams”	I2	Observation
	Comparison and reformulation of strategies	“let's try another way. If we divide first, it's easier”	I1, I3	Observation; group interaction
Collaborative learning	Peer discussion	Discussion of possible answers before presenting them to the class	I1, I2, I3	Observation
	Collective construction of strategies	Negotiation of different paths to solve the challenges	I1, I3	Collective production
Pedagogical mediation	Guiding questions	Instructor's requests for explanations of the procedures used	I1, I3	Observation
	Encouraging argumentation	Prompting justification of answers and comparison of the groups' strategies	I1, I2, I3	Observation; pedagogical records

Source: prepared by the authors (2026).

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Note: I1 = multiplication board game; I2 = mathematical market; I3 = challenge wheel. Quotations translated from Portuguese.

Chart 2 indicates that all four categories were present in the three interventions, although with different emphases: reasoning through numerical decomposition was most evident in the board game, comparison of quantities in the market, and collective construction of strategies in the challenge wheel. The following sections describe each intervention and discuss the findings in light of the literature.

4.3 Multiplication board game: calculation strategies and collective validation

In the board game (P1; Figure 1a), participants moved along the board by solving multiplications and problem situations presented on bonus cards. Observation records indicated high engagement, evidenced by interest in understanding the rules and participation in discussions. At several moments, the group discussed possible strategies before recording the answer, in a process of negotiation and collective validation of solutions.

Instead of relying exclusively on memorizing multiplication tables, some participants used numerical decomposition and additive reasoning. One of them explained: “four times six is twenty-four, so four times twelve is double” (*quatro vezes seis é vinte e quatro, então quatro vezes doze é o dobro*); another proposed an alternative path, stating that “adding eight three times also gives twenty-four” (*somar oito três vezes também dá vinte e quatro*). The first utterance mobilizes the associative property ($4 \times 12 = 4 \times 6 \times 2$), and the second, the meaning of multiplication as repeated addition, included in skill EF03MA07. The coexistence of strategies and their comparison by the group illustrate the calculation flexibility that the literature associates with mathematical proficiency (National Research Council) and with the pedagogical use of games to develop fluency and reasoning (Russo et al., “How Primary Teachers”).

Participants were also observed reformulating strategies after listening to their peers' explanations. Throughout the activity, the instructor asked participants to make their procedures explicit and justify them, which encouraged verbalization and mathematical argumentation.

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4.4 Mathematical market: comparing quantities in context

The market (P2; Figure 1b) simulated buying and selling situations to explore units of measurement, estimation, and comparison of quantities based on labels and packaging (EF03MA20). The classroom was set up as a market, with packages, price tags, play money, and a scale made by the pre-service teachers, and participants took on the roles of customers and sellers.

The records indicated that the activity fostered the interpretation and comparison of the mathematical information on the packages. When analyzing the relationship between quantity and price, one participant noted: “this one looks cheaper, but it has fewer grams” (*esse aqui parece mais barato, mas tem menos gramas*). This utterance reveals the beginning of proportional reasoning, the comparison of price per unit of mass, which goes beyond the intended skill and approaches mathematical literacy in consumer situations. Decisions were preceded by discussion among participants and by verbal explanation of choices, which confirms the potential of contextualized situations for the construction of meaning (Juandi et al.; Ausubel et al.).

4.5 Challenge wheel: collaborative problem solving

In the challenge wheel (P8; Figure 1c), problems were drawn at random and involved multiplication, parity, doubles and halves, as well as logical reasoning questions (for example, how many days there are in three weeks). Participants worked in small groups, discussing strategies before presenting their answers to the class. The draw generated anticipation and, subsequently, debates about the most appropriate procedures.

Different groups mobilized multiple paths for the same problem, comparing and reformulating strategies. In one record, a participant proposed revising the group's initial procedure: “let's try another way. If we divide first, it's easier” (*vamos tentar fazer de outro jeito. Se dividir primeiro fica mais fácil*). During the whole-class discussion, the instructor asked the groups to explain their reasoning and compare the strategies presented, a move that corresponds to the practices of selecting, sequencing, and connecting strategies described by Smith and Stein for orchestrating productive mathematics discussions.

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4.6 Pedagogical mediation and implications for pre-service education

In all three interventions, the moments of greatest mathematical depth, such as making properties explicit, comparing strategies, and justifying choices, occurred when the instructor posed guiding questions. This finding converges with the literature, according to which the effectiveness of games and manipulatives depends on intentional planning and the quality of teacher interventions (Lemes et al.; Andrade; Barros and Angelim; Batista and Miranda). In cultural-historical terms, teacher mediation turned playful interaction into a learning opportunity by challenging participants' answers within the zone of proximal development (Vygotsky; Farias and Bortolanza).

Comparing the documentary analysis with the observation of practices yields a central implication for pre-service education. The pre-service teachers' plans frequently incorporated playfulness, concrete materials, and group work, but rarely planned explicit moments of mathematical communication and justification, which emerged mainly from the teacher educator's mediation. This suggests that future teachers tend to appropriate first the visible aspects of active methodologies (the game, the material, the group), and only later their epistemic dimension (the discussion and validation of ideas). We therefore recommend that methodology courses include the explicit planning of questions, whole-class discussion, and synthesis as mandatory components of the lesson plan, in line with approximations of practice (Grossman et al.) and with the BNCC's focus on argumentation (Brasil, *Base Nacional*).

The results also broaden the debate on digital games in pre-service education. Contrary to what one might expect, the digital plans included fewer elements of active methodologies than the analog ones, because they prioritized individual competition and response time. This reinforces the need to discuss with pre-service teachers pedagogical criteria for choosing and designing digital games, beyond the motivational appeal of gamification (Pan et al.; Farias et al.; Ventura and Gomes).

4.7 Limitations

Some limitations should be considered. The study was conducted at a single institution with two groups of pre-service teachers, which limits the transferability of the findings. The activities were enacted as simulations among adult pre-service teachers,

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not with children; the strategies and interactions observed are therefore not necessarily equivalent to those that would emerge in actual early-years classrooms. The documentary analysis relied on what was explicitly recorded in the plans, so elements actually practiced but not written down may have been underestimated. Moreover, the design does not allow estimating the effect of the methodologies on mathematics achievement, and the dual role of the instructor-researcher may have influenced both the interactions and their interpretation. Future studies may include implementation with children, multiple classes and institutions, coding by independent judges with agreement statistics, and mixed designs with measures of achievement, self-efficacy, and mathematics anxiety.

5. Conclusion

This study analyzed how active learning methodologies were mobilized by pre-service pedagogy teachers when planning and enacting BNCC-aligned mathematics activities. The 11 plans analyzed covered all five thematic units and included, on average, almost five of the eight elements of active methodologies considered, with a predominance of playfulness, collaborative work, and concrete materials. In the three interventions analyzed in depth, the activities fostered participation, the use of diverse strategies, such as numerical decomposition and comparison of quantities, and the collective validation of solutions.

The study contributes by revealing an asymmetry between what future teachers plan and what actually makes an activity mathematically productive: argumentation was rarely planned, but emerged when the teacher educator asked participants to explain and compare their reasoning. It also indicates that digital games centered on time and ranking tend to include fewer elements of active learning. For pre-service education, we recommend treating mediation and argumentation as explicit objects of planning, articulated with the curricular organization of the BNCC.

As next steps, we suggest research with larger samples, longitudinal follow-up of graduates in their school practice, and mixed designs that integrate the analysis of interactions with measures of children's learning.

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Author contributions

Flaviane Melo de Anchieta and Luciano Carvalho Rapagnã: conceptualization; data curation; formal analysis; investigation; methodology; supervision; writing – original draft. Marcus Vinicius Gomes de Oliveira, Jaqueline Pereira de Azeredo Rapagnã, Laís Lemos Silva Novo Pinheiro, Juliana de Oliveira Lima Vianna, Luana Regina Ramos Caldeira Mata, and Rafael Rossi de Sousa: writing – review and editing.

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Conflict of interest

The authors declare no conflict of interest.

Data availability

The lesson-plan coding matrix and the analysis script are available as supplementary material. Observation records and reflective reports are not public in order to preserve the participants' anonymity, but may be requested from the authors with justification.

Declaration of Generative AI Use

During the preparation of this manuscript, the authors used Claude (Anthropic) for language editing, translation into English, reorganization of the text, adaptation to the journal's guidelines, and preparation of the figures from the coding matrix. All generated content was reviewed, corrected, and validated by the authors, who take full responsibility for the content of the publication.

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