Conceptual relationships in Freire, Piaget and Vygotsky used in the teaching and learning of mathematics and in teacher training

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Abstract
This study seeks to identify and describe which main concepts and perspectives in Freire, Piaget and Vygotsky are used in the process of teaching and learning Mathematics and in teacher training. To this end, qualitative, bibliographical, State of the Art research was carried out. The data obtained was communicated by the Brazilian Digital Library of Theses and Dissertations and the search was based on previously defined descriptors. From their analysis, it was found that Freire's concepts are widely used in the education of young people and adults; those of Piaget, in Early Childhood Education and early years; Vygotsky's cover, predominantly, from Early Childhood Education to Higher Education; and that all concepts are widely adopted in teacher training. Among the authors' contributions, the guaranteed assumptions of problematization, mediation, contextualization, games and active actions are common when looking for ways to teach Mathematics. Finally, it was found that, beyond the divergences in thought, the authors complement each other in constructing an interactionist view of learning.

Keywords
theoretical contributions; interactionism; mathematic; pedagogical practices.

Relações conceituais em Freire, Piaget e Vygotsky utilizadas no ensino e aprendizagem da Matemática e na formação de professores

Resumo
Este estudo busca identificar e descrever quais principais conceitos e perspectivas em Freire, Piaget e Vygotsky são utilizados no processo de ensino e aprendizagem da Matemática e na formação de professores. Para isso fez-se uma pesquisa qualitativa, bibliográfica, do tipo estado da arte. Os dados obtidos advieram da Biblioteca Digital Brasileira de Teses e Dissertações e tiveram sua busca pautada em descritores previamente definidos. Da análise destes, constatou-se que os conceitos de Freire são bastante utilizados na educação de jovens e adultos; os de Piaget, na Educação Infantil e anos iniciais; os de Vygotsky abarcam, predominantemente, da Educação Infantil ao Ensino Superior; e que todos os conceitos são largamente adotados na formação de professores. Dentre as contribuições destes autores, os pressupostos vinculados à problematização, mediação, contextualização, jogos e fazeres ativos são comuns quando se buscam

caminhos para o ensino de Matemática. Por fim, constatou-se que, para além das divergências no pensamento, os autores se complementam na construção de uma visão interacionista da aprendizagem.

Palavras-chave
contribuições teóricas; interacionismo; Matemática; práticas pedagógicas.

Conceptual relationships used in Freire, Piaget y Vygotsky en la enseñanza y el aprendizaje de las Matemáticas y en la formación docente

Resumen
This study seeks to identify the main concepts and perspectives of Freire, Piaget y Vygotsky se utilizan en el proceso de enseñanza y aprendizaje de las Matemáticas y en la formación docente. Para ello se realizó una investigación cualitativa, bibliográfico, de Estado del Arte. Los datos obtenidos fueron comunicados por la Biblioteca Digital Brasileña de Tesis y Disertaciones y la búsqueda se basó en descriptores anteriorly defined. De su análisis se encontró que los conceptos de Freire son amplamente utilizados en la educación de jóvenes y adultos; los de Piaget, en Educación Infantil y Primera Edad; la portada de Vygotsky, predominantly, desde la Educación Infantil hasta la Educación Superior; y que todos los conceptos son amplamente adoidos en la formación docente. Entre los aportes de los autores, son comunes los supuestos garantizados de problematización, mediación, contextualización, juegos y acciones activas a la hora de busca formas de enseñar Matemáticas. Finally, it is found that, más allá de las divergencias de pensamiento, los autores se complementan en la construcción de una visión interaccionista del aprendizaje.

Palabras clave
interaccionismo; aportes teóricos; Matemática; prácticas pedagógicas.

1 Introduction

Mathematics teaching has traditionally been approached in a vertical, sequential and individualistic way, with the teacher transmitting ready knowledge and passive students, receivers, memorizing and reproducing formulas. However, in recent years, after debates and official recommendations, teaching approaches that value the interaction between the actors of the schooling process and the learning environment have gained prominence.

Documents, such as the National Common Curricular Base (BNCC), which admit that students are “[...] subjects with stories and knowledge built in interactions with other people, both from the closest social environment and from the universe of media and digital culture” (Brasil, 2018, p. 61-62), emphasize the construction of knowledge through

interaction, promoting dynamic and participatory perspectives of teaching and learning processes, which do not occur in isolation, but through significant interactions between students, between the teacher and students and between them and the mathematical content.

Sharing a similar thought, this work understands that "[...] learning is a process that begins from the confrontation between objective reality and the different meanings that each person constructs about this reality, considering individual experiences and existing social rules" (Antunes, 2008, p. 32). We consider, therefore, that the school institution is a learning space with robust possibilities of interaction between all agents involved in the process (students, teachers, managers, etc.) and between them and the environment with its peculiarities.

In this sense, when approaching interaction, we must remember the contributions of Immanuel Kant (1724-1804), who, with the elaboration of his philosophical conceptions, proposed the junction of reason (internal/subject) and empiricism (external/environment), thus uniting the concatenation of thoughts with world experiences. From this agglutination that adds previously separated currents, interactionism emerges as a pedagogical strand that believes in the potential of the subjects' interrelationship with the environment and with objects, assuming a preponderant role in the construction of knowledge.

Thus, it is important to resort to the theoretical perspectives presented by the interactionist exponents: Paulo Freire (1921-1997), Piaget (1896-1980) and Vygotsky (1896-1934) when trying to understand the mechanisms of teaching practice and student action that may be reflected in the teaching and learning process, specifically in Mathematics, a science that lacks incisive and effective pedagogical interventions due to a whole accentuated problem related to school knowledge and practices.

Freire, in his liberating pedagogy, resignifies some concepts of Piaget and Vygotsky, among them: play, language, autonomy, culture, problematization and contextualization. In addition, the patron of Brazilian education elevates and transposes them, adding humanistic, critical and supportive traits. Piaget's constructivism considers knowledge to be a student's own construction and, therefore, not something transmitted (Krasilchik, 2002). For Vygotsky (1988), human learning is an active process, in which there are purposeful actions mediated by various signs and tools.

In principle, we realize that the interactionist approach in mathematics teaching values mediation, autonomy, contextualization, problem solving, play/game and proactivity as central instances. By engaging students in challenging and meaningful situations, mathematical concepts become more relevant and concrete. In addition, interactive didactic-pedagogical possibilities promote cooperation, communication and the development of social skills, which are essential for both mathematics and life in society.

Based on this initial hypothesis, this work arises with the following question: what are the main concepts of Freire, Piaget and Vygotsky used in the process of teaching and learning mathematics and linked to teacher training? It seeks, therefore, to map, among the many contributions brought by theorists, which conceptual bases are most used in school practices, specifically related to mathematics teaching and teacher training.

Thus, when we recognize the importance of the legacy of each theorist mentioned and the interaction, in its various facets, for mathematical learning, we hope, when searching for answers to the main question of this research, to point out pedagogical paths and possibilities and contribute to the improvement of educational practices, promoting a more engaging, meaningful and effective teaching, especially in the field of Mathematics, without aiming at the exhaustion of the theme.

2 Methodology

This work consists of a qualitative and procedurally bibliographic research, developed based on books, theses, among other publications. It is a mapping of scientific production on a given subject in certain circumstances. Briefly, state-of-the-art type surveys are:

> Defined as bibliographic, they seem to have in common the challenge of mapping and discussing a certain academic production in different fields of knowledge, trying to answer which aspects and dimensions have been highlighted and favored in different times and places, in which ways and under what conditions certain master's dissertations, doctoral theses, publications in journals and communications in annals of congresses and seminars have been produced (Ferreira, 2002, p. 258).

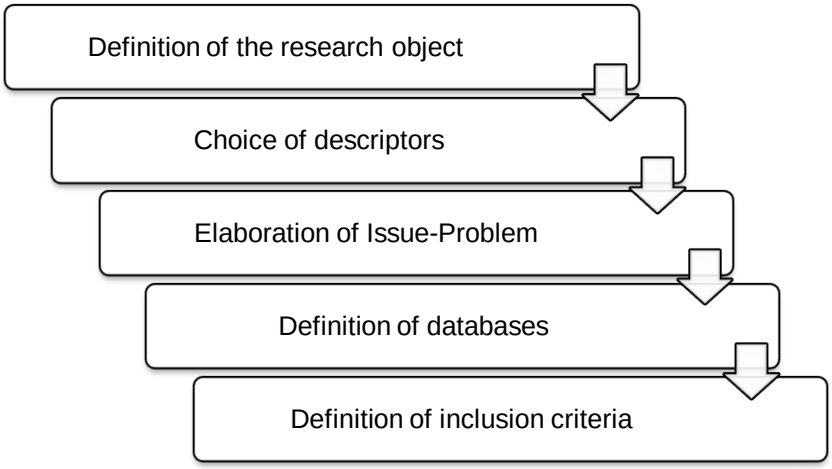
In this proposal for the investigation of scientific production, we specifically focus on concepts brought by Freire, Piaget and Vygotsky that have been used to promote improvements, specifically in the teaching and learning of Mathematics. For this, we did

not establish a specific level or modality of teaching and education, respectively, because curiosity is based on a general context that involves hypothetical-deductive logic.

This investigative path assumes that state-of-the-art or state-of-the-art studies are recognized for involving a large number of works and for seeking to describe general aspects or trends of research in a given area of knowledge, highlighting its main concepts, results and conclusions and making a synthesis of the knowledge produced (Fiorentini *et al.*, 2016). We reinforce, therefore, that the state of the art is an important systematization of scientific research, as it guides the researcher regarding the relevance of the object under study and improves it in relation to the development of other perspectives, thus enabling new investigations on the subject. We emphasize that the theoretical contribution of each study, in addition to serving as a guide for the research process, denotes the authors' perspective on the subject (Garcia; Santos; Trindade, 2024).

In this work, the steps represented in flowchart 1 were followed, but not necessarily in the same order as the scheme.

Flowchart 1 – State of the Art Steps



Source: Own authorship (2024).

As already mentioned, some of the interactionist concepts brought by Freire, Piaget and Vygotsky and their appropriations to the teaching of Mathematics were explored. We emphasize that all research, except those carried out in books, were carried out in the Digital Bank of Theses and Dissertations (BDTD) and that, to facilitate the understanding of the data, we emphasize that the publications considered relevant found were separated and discussed by descriptors or keywords.

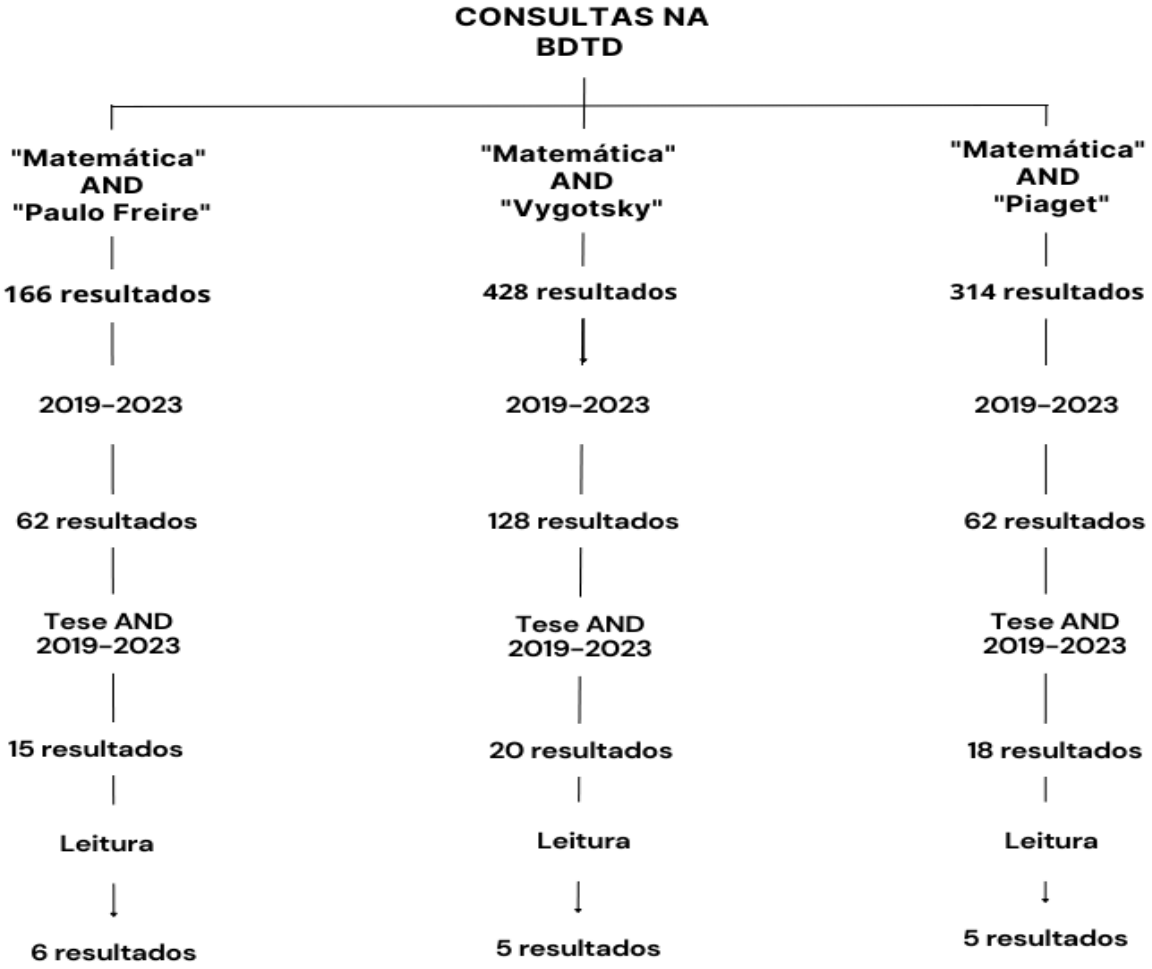
In our initial search on BDTD, we used the descriptors “Paulo Freire” and *(AND)* “Mathematics” in the “all fields” filter, as indicated on the platform. The query returned 166 results. When assigning as inclusion criteria only the works published in the last five years (2019-2023), we found 62 studies. In addition to the time frame, we added another criterion: only theses. Once this was done, we obtained a total of 15 publications. Of these, after reading the abstracts, nine were excluded because they did not meet our interest, so, finally, only six works were considered, as shown in Table 1 (Results and discussion section).

Similarly, when we searched the publications using the descriptors “Vygotsky” and *(AND)* “Mathematics,” with citations of the terms across all fields, we found 428 publications. Of these, when applying the five-year interval as a filter (2019-2023), the database returned 128 documents, between theses and dissertations. Finally, applying the "thesis" filter to search only for works of this type, the result was 20 studies. Of these, after reading the abstract, five were selected for adhering to our object of study, as shown in Table 2 (Results and discussion section).

The same search was conducted using the descriptors “Piaget” and *(AND)* “Mathematics.” We found 314 publications, which, when filtered considering only the last five years (2019-2023), gave way to 62 works. When we refined the search and established that only theses would be accepted, the result fell to 18 documents. When we read the summary, we found that five of them would be useful for our systematization. These are shown in Table 3 (Results and discussion section).

In view of the report on the consultation carried out in the BDTD, Flowchart 2 seeks to simplify the descriptions and graphically show how the consultations took place based on the determination of the descriptors and their respective filters.

Flowchart 2 – Consultations carried out at BDTD



Source: Own authorship (2024).

Data analysis was conducted through careful readings of the selected materials. This approach allowed an in-depth understanding of the concepts presented by the selected authors: Freire, Piaget and Vygotsky. The readings of the abstract, theoretical part and results were carried out in a systematic and thorough manner, in order to extract relevant information for the research.

During the analysis process, we identified the main concepts addressed by each author, as well as their respective appropriations at different levels of mathematics education. From this, we prepared summaries, notes and detailed records of the relevant passages, ensuring the accuracy and fidelity of the information collected. We emphasize that the entire analysis is qualitative, but considering some objectivities.

3 Results and discussion

For a better understanding of the data, as already mentioned, we segregated the queries by theorists (Freire, Piaget and Vygotsky) and analyzed them separately.

3.1 Freire and Mathematics

Table 1 shows the six theses selected after a careful refinement process carried out at BDTD.

Table 1 - Theses that relate Freire's concepts to the teaching of Mathematics.

Year	Title	Author
2022	Mathematics education with the youth and adult class at Agrovila Campinas: a study with mathematical modeling	Osti, Mariele de Freitas
2022	Mathematical modeling: students' looks after the development of an activity	Souza, Lahis Braga
2022	Dreams of socially disadvantaged adolescents: life, school and mathematics education	Soares, Daniela Alves
2021	Initial training of teachers who teach Mathematics: looks and movements based on Ethnomathematics	Costa, Rodrigo Tadeu Pereira da
2021	Financial education in the context of mathematics education: possibilities for initial teacher education	BARONI, Ana Karina Cancian.
2020	Digital technologies in mathematics education with young people and adults: a look at CIEJA/Campo Limpo	Silva, Jonson Ney Dias da

Source: Own authorship (2023).

As described in the methodological path, after organizing the theses, we started the reading process, this time with a careful look, always seeking information relevant to the research. We subsequently carried out a synthesis of each work.

The thesis "*Mathematics education with the youth and adult class at Agrovila Campinas: a study with mathematical modeling"*, published in 2022, focuses on everyday practices and, for this, makes use of mathematical modeling, which, according to author Mariele de Freitas Osti, has a relevant role in the receptivity of students to the content. When dealing with these practical applications, the author focuses on contextualization and practical applications.

Lahis Braga Souza, in their work " *Mathematical modeling: students' looks after the development of an activity,"* published in 2022, discusses mathematical modeling as a catalyst for problematization. The author advocates the importance of collaboration among

students in the development of mathematical activities as a means of understanding the social role of mathematics.

The work *"Dreams of socially disadvantaged adolescents: life, school and mathematics education"*, by researcher Daniela Alves Soares, published in 2022, works on the concepts of dream, transcendence, being more, unfinished, alterity, among others. She does this based on Paulo Freire and uses other theorists as a complement. On the occasion, the author argues that the struggle for more room for dreams in the school environment and in mathematics classes cannot be dissociated from the struggle for social justice.

In her thesis on teacher education titled " *Financial education in the context of mathematics education: possibilities for initial teacher education*," published in 2021, Ana Karina Cancian Baroni emphasizes the emancipatory role of education. She advocates for teaching from an interdisciplinary perspective, highlighting the importance of understanding the world around us. The author, therefore, focuses on critical mathematics education and dialogicity as elements of overcoming reductionist views that base this area of mathematics as a stimulator of consumption, devoid of a broad and contextualized debate.

In "*Initial training of teachers who teach Mathematics: looks and movements based on Ethnomathematics",* published in 2021, Rodrigo Tadeu Pereira da Costa advocates for viewing mathematics as a sociocultural production and emphasizes the importance of dialogue between scientific knowledge and everyday understandings. The focus is on the many mathematics practiced in the most diverse environments and cultures.

From the analyzes, we realized that all these bring the importance of relating mathematical content to everyday life, considering the context. This is one of the main recommendations of *Freire's* pedagogy contained in official documents, such as the BNCC, when it advocates a directed mathematical action "[...] to solve problems, applying concepts, procedures and results to obtain solutions and interpret them according to the contexts of the situations" (Brasil, 2018, p. 265). Therefore, based on the publications, contextualization, in a practical conception, is the main concept used by those who seek to relate Paulo Freire's legacy to mathematics teaching. For the educator, it is unethical to promote educational practices unrelated to the "[...] social, cultural, economic conditions of their students, their families, their neighbors" (Freire, 2004, p. 63).

It is true that practically all the works analyzed discuss teacher training and issues related to youth and adult education, discussions that are partially beyond our research interest, but that were considered for the possible contributions to mathematical teaching and learning in any situation, provided that the necessary adaptations are made.

3.2 Vygotsky and mathematics

Table 2 presents the works analyzed after filtering theses that contain Vygotsky's contributions to mathematics teaching.

Table 2 – Theses that relate Vygotsky's concepts to the teaching of Mathematics.

Year	Title	Author
2022	Study of the quadratic function using the GeoGebra *software* from the perspective of Historical-Cultural Theory: expansive transformations	Xavier, José Fábio
2021	Appropriation of mathematical concepts in Early Childhood Education in the light of Historical-Cultural Theory: between talking, living and playing	Miranda, Maria Auristela Barbosa Alves de
2020	Meaning of plane geometry concepts by teachers in training activity	Moura, Kelly Cristine Rodrigues de
2020	Continuing education in mathematics for teachers in the early years of elementary school: construction of autonomous identities and the problematization of educational reality	Bemme, Luis Sebastião Barbosa
2019	Learning Triggering Problems in Teaching Organization: Moving Senses in Mathematics Teacher Education	Virgens, Wellington Pereira das

Source: Own authorship (2023).

Building on Vygotsky and referencing Leontiev, Davidov, Zankov, and Engeström, José Fábio Xavier, in his thesis *Study of the quadratic function using the GeoGebra software from the perspective of Historical-Cultural Theory: expansive transformations*, published in 2022, examines the concept of mediation by questioning whether new technologies, particularly digital ones, facilitate critical reflection as mediators in teaching and learning processes. The thesis he arrives at is that the expansive learning approach has the potential to break with the traditional model.

The thesis titled "*Appropriation of mathematical concepts in Early Childhood Education in the light of Historical-Cultural Theory: between talking, living and playing"*, published in 2021 by Maria Auristela Barbosa Alves de Miranda, analyzes the appropriation of mathematical concepts in early childhood education. It considers the relationships between what is spoken and what is experienced in the processes of presenting and internalizing mathematical concepts, highlighting their connections to play.

Researcher Kelly Cristine Rodrigues de Moura, in her work "*Significance of plane geometry concepts by teachers in training activity",* published in 2020, investigates the process of signification of plane geometry concepts by teachers in training and defends the qualitative leap from mediation via teaching guidance activity (AOE) in relation to plane geometry concepts.

In the work "*Continuing education in mathematics for teachers in the early years of elementary school: construction of autonomous identities and the problematization of educational reality"*, published in 2020, Luis Sebastião Barbosa Bemme argues that a formative space, organized under the principles of a community of practice, favors the process of discussion and apprehension of meanings, which enhances teaching learning of both the specific and pedagogical knowledge of the subjects involved. The bases of problematizing learning and aligned with the awakening of autonomy are present.

Finally, researcher Wellington Pereira das Virgens, in his thesis titled "*Learning Triggering Problems in Teaching Organization: Moving Senses in Mathematics Teacher Education*", published in 2019, employs the concepts of problematization to indicate that teacher training activities aim to raise the subject's awareness of their role in the pedagogical process.

In Vygotsky, we realize that the concept of mediation is present in all the work carried out. This constitutes a central theoretical-philosophical foundation of the Russian psychologist. The readings of the theses point to the indispensability of mediation in human formation, in educational terms, which should occur mainly in the first school years.

It is important to emphasize that Vygotsky's theoretical perspectives are easily applicable at all levels and modalities of teaching and that mediation, in the author's conception, means a "[...] process of intervention of an intermediate element in a relationship; the relationship then ceases to be direct and becomes mediated by this element" (Oliveira, 1993, p. 26).

3.3 Piaget and Mathematics

Finally, we analyze the theses in Table 3, which deal with aspects of Piaget's legacy and his contributions to mathematics teaching.

Table 3 - Theses that relate Piaget's concepts to the teaching of Mathematics.

Year	Title	Author
2021	Mathematics Teaching: Teaching Design and Doing didactic-pedagogical	Silva Neto, João Ferreira da
2021	Active methodologies in the training of Pedagogy students for the construction of mathematical knowledge in Elementary School Early Years	Santos, Emerson da Silva dos
2020	Dynamic geometry and instrumental genesis: a process of reflective abstraction	Medeiros, Margarete Farias
2019	The Matgomoku board game for teaching 1st grade polynomial function: limits and potentialities	Fernandes, Natanaildo Barbosa
2019	A continuing education, through didactic engineering, of multipurpose teachers with a focus on pedagogical knowledge and practices related to the concept of natural number	Lomasso, Emerson Bastos

Source: Own authorship (2023).

João Ferreira da Silva Neto, when defending his thesis, entitled "*Mathematics Teaching: Teaching Design and Doing didactic-pedagogical"*, published in 2021, analyzes the tensions between the predominant epistemological and pedagogical conceptions in the school and the teaching practice of the mathematics teacher, identifying limits and possibilities in the construction of teaching autonomy. The author discusses autonomy and constructivism as potentializing mechanisms of mathematical learning.

In the work, "*Active methodologies in the training of Pedagogy students for the construction of mathematical knowledge in Elementary School Early Years"*, published in 2021, Emerson Silva Santos discusses how active methodologies can contribute to the development of logical-mathematical thinking. For this, he uses Piaget's theory and uses concepts of serialization, classification and conservation.

Researcher Margarete Farias Medeiros, in her thesis, entitled "*Dynamic geometry and instrumental genesis: a process of reflective abstraction"*, published in 2020, discusses the ability of a person to reflect on their own thoughts, actions and experiences in a more systematic and metacognitive way. The author makes use of Geogebra 3D when dealing with spatial geometry content and complements her studies with Rabardel's theory of Instrumental Genesis. The text presents concepts of formal operations and elements of hypothetical-deductive thinking.

The thesis "*The Matgomoku board game for teaching 1st grade polynomial function: limits and potentialities"*, defended by Natanaildo Barbosa Fernandes in 2019, discusses the use of educational games in the process of teaching and learning

mathematics. The author presents the possibility of working with the playful allied to formal education.

The work titled, "*A continuing education, through didactic engineering, of multipurpose teachers with a focus on pedagogical knowledge and practices related to the concept of natural number"*, published in 2019 by Emerson Bastos Lomasso, conceptualizes the natural number based on Piaget (and Szeminska). It employs various concepts, including the conservation of quantities and one-to-one correspondences, which are assimilated during the concrete operational stage.

Among the concepts present in the works that relate Piaget to mathematics teaching, we realize that the active role of the student is the most used. It is directly related to active, constructivist pedagogical practices, decisive to the process of assimilation in the author's view. The concept of play is also explored with reasonable intensity and deserves to be highlighted in school mathematics, because, as a didactic resource, it leads the student to play an active role in the construction of their knowledge (Dante, 2000).

Regarding the concept of game, Huizinga (2010, p. 33) defines it as one:

> [...] voluntary activity or occupation, carried out within certain limits of time and space, according to rules freely consented to, but absolutely obligatory, endowed with an end in itself, accompanied by a feeling of tension and joy and an awareness of being different from everyday life.

Thus, we found that the theoretical perspective brought by Piaget is highly appreciated in the continuing education of teachers, especially pedagogues who work in the early grades and teach mathematics. The focus of the discussions, however, falls on teaching and learning processes in early childhood education and early grades. In these, concepts of numbers, serialization, classification, among others, are explored in order to begin the construction of mathematical thinking and lay the foundations for complex reflections that appeal to symbolism and future formal propositions.

5 Final Considerations

After analyzing the previous data, we noticed, in relation to the process of teaching and learning Mathematics, that: a) most of the studies on Freire and Vygotsky deal with

teacher training; b) mediation, problematization and contextualization are the most used contributions by those seeking to improve their practices in the classroom; c) Piaget-based practices highly value active pedagogies, games and conceptual training; and d) most research addresses problems of basic education, although there are many teacher training.

We emphasize that, as no level or modality of education was specified, the search took place in a broad way. We confirm that Freire's concepts are widely used in youth and adult education; those of Piaget, in Early Childhood Education and in the early years; those of Vygotsky most often cover a horizon ranging from Early Childhood Education to Higher Education. We emphasize that all the concepts brought by these authors are exhaustively worked out in processes that involve teacher training. Such concepts, however, are not restricted to a specific type of teacher education or to levels and modalities of teaching, but are accessed from a broad perspective and many educators incorporate them into their practices, in different educational contexts, adapting them to the needs and characteristics of their students.

The concepts of problematization, contextualization and active practices are common to the theorists studied. From the readings and studies carried out, we verified that, in addition to divergences of thoughts, the theoretical perspectives of the aforementioned authors complement each other and, when added together, have enormous potential to promote the improvement of mathematics teaching.

6 Acknowledgements

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