

A literature review on the pedagogical practices of teachers who teach geometry

Um estudo da literatura sobre práticas pedagógicas de professores que ensinam geometria

Una revisión bibliográfica sobre las prácticas pedagógicas de los profesores que enseñan geometría

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Resumo

Ao possuir como elemento norteador o uso de abordagens teóricas para conduzir a compreensão de aspectos da prática pedagógica de professores como uma ação mediada, o presente artigo teve como objetivo *identificar e descrever o modo como a prática pedagógica de professores que ensinam geometria é tratada em estudos científicos*. Para tal, realizou-se uma revisão sistemática de literatura, composta por 30 artigos das bases de dados Latindex e ERIC, examinados de acordo com as seguintes unidades de análise: ano de publicação; país de realização da pesquisa; abordagens teóricas; ferramenta cultural; conteúdo de geometria; nível de ensino; metodologia de pesquisa; e instrumentos de constituição de dados. Apesar de ter se constatado a presença de diversos conteúdos de geometria em variados níveis de ensino, os resultados indicaram tendências em abordar o conhecimento e a atuação docente sem a consideração de seus aspectos subjetivos, o que foi corroborado pelas ferramentas culturais, pelos instrumentos de constituição de dados utilizados e pela ocorrência de pesquisas quantitativas. Ressalta-se a necessidade de abordar mais profundamente a ação mediada que é a prática pedagógica de professores que ensinam geometria, integrando os aspectos práticos e subjetivos que a compõem, principalmente em pesquisas realizadas no Brasil, a fim de que tais pesquisas possam efetivamente contribuir para a prática pedagógica do professor em sala de aula.

Palavras-chave: rática pedagógica do professor. Ensino de geometria. Pesquisa bibliográfica.

Abstract

By using theoretical approaches as a guiding element to understand aspects of teachers' pedagogical practice as a mediated action, this article aimed to *identify and describe how the pedagogical practice of teachers who teach geometry is treated in scientific studies*. To this end, a systematic literature review was conducted, comprising 30 articles from the Latindex and ERIC databases, examined according to the following units of analysis: year of publication; country where the research was conducted; theoretical approaches; cultural tool; geometry content; educational level; research methodology; and data collection instruments. Although the presence of diverse geometry content across different educational levels was observed, the results indicated tendencies to address knowledge and teaching practice without considering their subjective aspects. This was corroborated by the cultural tools, the data construction instruments employed, and the occurrence of quantitative research. The need to examine more deeply the mediated action that constitutes the pedagogical practice of teachers who teach geometry is highlighted, integrating the practical and subjective aspects that compose it, particularly in research conducted in Brazil, so that such research can effectively contribute to the teacher's pedagogical practice in the classroom.

Keywords: Teacher pedagogical practice. Geometry teaching. Bibliographic research.

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Resumen

Mediante el uso de enfoques teóricos como elemento orientador para comprender aspectos de la práctica pedagógica de los docentes como una acción mediada, este artículo tuvo como objetivo *identificar y describir cómo se aborda la práctica pedagógica de los docentes que enseñan geometría en los estudios científicos*. Para ello, se realizó una revisión sistemática de la literatura, compuesta por 30 artículos de las bases de datos Latindex y ERIC, examinados según las siguientes unidades de análisis: año de publicación; país donde se realizó la investigación; enfoques teóricos; herramienta cultural; contenido geométrico; nivel educativo; metodología de investigación; y instrumentos de recolección de datos. Aunque se constató la presencia de diversos contenidos de geometría en distintos niveles de enseñanza, los resultados indicaron tendencias a abordar el conocimiento y la actuación docente sin considerar sus aspectos subjetivos, lo cual fue corroborado por las herramientas culturales, los instrumentos de construcción de datos utilizados y la presencia de investigaciones cuantitativas. Se destaca la necesidad de abordar con mayor profundidad la acción mediada que constituye la práctica pedagógica de los docentes que enseñan geometría, integrando los aspectos prácticos y subjetivos que la componen, especialmente en investigaciones realizadas en Brasil, para que dicha investigación pueda contribuir eficazmente a la práctica pedagógica del profesor en el aula.

Palabras clave: Práctica pedagógica del profesor. Enseñanza de la geometría. Investigación bibliográfica.

1. Introduction

Just like any profession, teaching requires specific knowledge. Nóvoa (2022, p. 8) presents professional teaching knowledge as

a knowledge that is in teaching, that is, that is elaborated in action (*contingent*); a knowledge that is in the profession, that is, that is defined in a dynamics of sharing and co-construction [*sic*] (*collective*); a knowledge that is in society, that is, that projects itself outside the professional sphere and asserts itself in a broader (*public*) space.

However, the construction of knowledge, no matter how profound, is not enough for the teacher to fully achieve their teaching objectives. Silva and Silva (2022) point out that intentionality should be added to professional teaching knowledge, that students should be considered as social subjects with identities and singularities, and that their previous experiences and knowledge should be taken into account in the construction of new knowledge. The authors indicate that the teacher's experiences and particularities are also part of this context, along with the social and educational context in which all the aspects mentioned above are situated. Thus, teachers' pedagogical practices are constituted by theoretical and practical elements and are characterized by the set of teachers' knowledge (content, pedagogical, methodological, among others), endowed with intentionality, allied to teachers' values and students' demands, in a given teaching context.

Thus, teachers' pedagogical practices cannot be generalized and must be rethought and remodeled according to the needs of the agents involved in the teaching and learning process (Silva; Silva, 2022). Therefore, theoretical approaches underlie such practices.

Teaching is important in the development of humanity and its *utilitarian* aspects, with their daily applications; *formative*, as it constitutes more attentive and socially engaged individuals; and *resolutive*, since it contributes to the resolution of problems in several professions. Silva and Rodrigues (2025, p. 8) argue that the teaching of geometry at school is relevant for several reasons:

[...] Geometry is deeply connected to several areas of knowledge, such as physics, art, architecture, and biology, expanding the possibilities of practical application of what is learned in the classroom. This interdisciplinary character contributes to a broader understanding of the world.

Despite its importance, the emphasis given to geometry in current curricula has declined significantly, owing to interconnected factors, such as the prioritization of algebra, as it predominates in large-scale assessments; students' difficulties in solving spatial and abstract problems; and teachers' lack of time to address such content, which stems from changes in Brazil's curriculum guidelines that reduced the time and depth with which geometry is addressed in the classroom (Silva; Rodrigues, 2025). Moran *et al.* (2023) indicate that there are gaps in the teaching of this mathematical content, which may stem from the fact that the geometry addressed in initial teacher education does not match the content to be taught by prospective teachers. Gumiero and Pazuch (2024) add that, although the teaching of geometry content has changed over the last few years, it is still approached in a standardized and objective way, without valuing the development of students' reasoning. According to Silva and Rodrigues (2025, p. 16), "to reverse this situation, it is essential to rethink pedagogical practices, invest in teacher education and establish clearer connections between geometric concepts".

Although the pedagogical practice of the teacher who teaches geometry is not dissociated from that of the teacher who teaches mathematics, the gaps highlighted above underscore the need for a focused look at the teaching processes that specifically concern this mathematical content. It is necessary to understand how research on geometry teaching is being guided, how these practices are characterized, and which paths are pointed out to improve them. Thus, this article seeks to answer the following question: *how are theoretical approaches used to guide studies on the mediated action that constitutes the pedagogical practice of teachers who teach geometry?* To address it, the following objective was formulated: *to identify and describe how the pedagogical practice of teachers who teach geometry is treated in scientific studies.* To this end, a systematic literature review was conducted, in order to understand the directions that research has taken and to contribute to the teaching of this mathematical content. The theoretical framework, methodological procedures, results, discussions, and final considerations of the review are presented below.

2. Theoretical framework

In their pedagogical practices, teachers use varied strategies for different purposes. Therefore, teachers' pedagogical practice can be characterized as a *mediated action*. For Wertsch (1991, 1998), a mediated action is composed of an agent and a mediational means, which constitute a single unit and must be analyzed together. The author also states that both the agent and the mediational means are situated in a given sociocultural context, subject to cultural, institutional, and historical aspects. Thus, the mediated action is considered an irreducible unit, since a fragmented analysis of its components can result in a superficial investigation and mischaracterize the phenomenon being observed. However, this irreducibility does not prevent such elements from being identified. They should, nevertheless, be observed in connection with the context in which they are situated, considering how they interact.

The author also indicates that mediational means are *cultural tools* that, like the agents and the action in which they are used, are products of a given historical, social, and cultural context. Such tools can be characterized as technical; as manipulative materials—blackboards, digital technologies—; or as psychological, such as problem solving and group discussions.

To carry out the same action, different cultural tools exist and can be used; that is, the agent has a “*toolkit*” at their disposal. The choice of these tools can be motivated by varied factors, depending, for example, on the teacher’s objectives, methodological options, and students’ skills and understanding. Therefore, mastery of a cultural tool (the acquisition of the knowledge necessary to use it) does not necessarily imply its appropriation—the insertion of a cultural tool into a given context, taking it as one’s own (Wertsch, 1998).

In the field of Mathematics Education, Barbosa (2018) conceptualizes theoretical approaches as sets of constructs that provide knowledge and problematizations about the nature of a given context. The author adds that such approaches should be organized in a horizontal structure, since, although they present a certain distance from one another, one approach does not cancel out or override another; that is, there should be no hierarchy in which one approach is considered superior to another. On the contrary, the different ways of conducting research demand the coexistence of varied theoretical approaches that adapt to different research objectives and that can even be articulated in certain situations.

Barbosa (2018) highlights four theoretical approaches: *teacher thinking*, *technological mediation*, *contextual* and *post-contextual*. Teacher thinking approaches deal with the teacher’s actions in the classroom, arising from their knowledge, whether of mathematical content or of didactic-pedagogical content. In technological mediation approaches, digital technologies play an active role in teaching and learning processes, giving them unique characteristics—and the absence of digital technologies would result in the disfigurement of these processes. Contextual approaches emphasize the influence of context on teaching practice. Therefore, school culture and the process of professional socialization, integrated with historical, social, and cultural aspects, are emphasized in these approaches. Finally, post-contextual approaches seek to transgress and problematize the boundaries established by the contexts of contextual approaches.

Thus, the teacher’s pedagogical practice is considered a mediated action, in which the agent is the teacher and the cultural tools are the means teachers use to put into action the pedagogical practice of the teacher who teaches geometry or, further, to understand how such practice occurs. This mediated action can be investigated through different theoretical approaches. In order to understand how theoretical approaches are used to guide studies on the mediated action that constitutes the pedagogical practice of teachers who teach geometry, a systematic literature review was conducted, whose procedures are presented below.

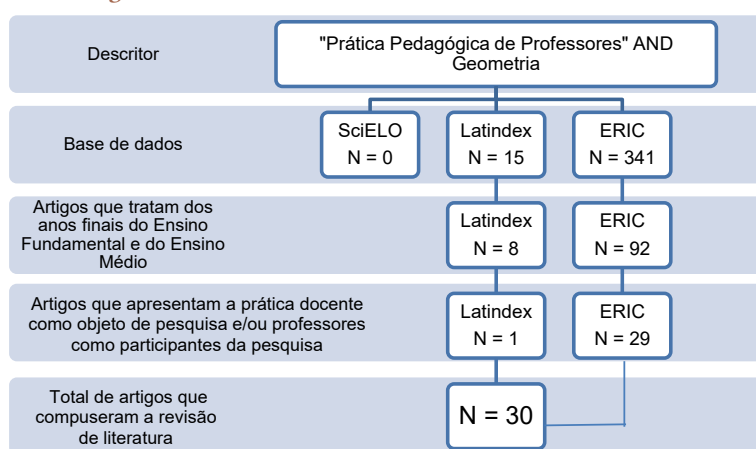
3. Methodological procedures

Barbosa (2018) points out that a systematic literature review consists of a synthesis of a specific body of literature guided by a specific question or objective, with a given purpose. Thus, the *corpus* of literature is obtained through rigorous and well-established criteria, aiming to systematize results and highlight possible gaps in relation to the objectives in question. Such gaps can be transmuted into new possibilities for studies in the research field in question.

Thus, the following criteria were established for this literature review: (a) articles published in the SciELO, Latindex¹ and ERIC databases, in order to include research conducted in English (ERIC), including Brazil (SciELO) and Latin American countries (Latindex), so that the aspects observed would converge more closely with the context of Brazilian education; (b) articles published from January 2014 to December 2023, in order to narrow the sample to articles dealing with more current issues in relation to the objective in question; (c) research articles published in Portuguese, Spanish or English; (d) articles whose descriptors were identified in the title, abstract and/or keywords.

For the search, the descriptor “Práticas Pedagógicas de Professores” AND Geometria was used, together with its respective translation into English or Spanish when necessary². The number of articles found in the initial search, as well as the additional selection criteria, are presented in Figure 1.

Figura 1 – Selection criteria and number of articles obtained



Source: authors' own elaboration

Thus, this literature review was composed of 30 articles. The articles were analyzed following the structure proposed by Gumiero and Pazuch (2024). Thus, they were analyzed vertically, that is, individually, one by one, based on pre-established units of analysis; and horizontally, by analyzing the units of analysis of all articles simultaneously, one by one. The articles that comprised the literature review are presented in Table 1.

¹In Latindex, journals on Mathematics Education and/or Teaching, listed in Catalog 2.0 under the theme Exact and Natural Sciences and the subtheme Mathematics, were selected. Of these, 19 journals were selected.

²When necessary, quotation marks were used to ensure that the descriptor was considered a single term; and the conjunction AND, to ensure that both descriptors were searched simultaneously. Translation into English: “Teachers Pedagogical Practices” AND Geometry. Translation into Spanish: “Prácticas pedagógicas de los docentes” AND Geometría.

Table 1 – Articles obtained with the descriptor “pedagogical practices of teachers” AND geometry

No.	Title	Author(s)	Database
1	“Conocimiento del profesor de secundaria de la práctica matemática en clases de geometría” [Secondary school teacher's knowledge of mathematical practice in geometry classes]	D. Zakaryan and L. Sosa	Latindex
2	“A case study of two selected teachers as they integrated dynamic geometry software as a visualization tool in teaching geometry”	D. Mavani, B. Mavani and M. Schäfer	ERIC
3	“In-service mathematics teachers' knowledge and awareness of ethnomathematics approaches”	G. Sunzuma and A. Maharaj	ERIC
4	“From defining as assertion to defining as explaining meaning: teachers' learning through theory-informed lesson study”	J. Adler, L. Mwadzaangati and S. Takker	ERIC
5	“In-service zimbabwean teachers' views on the utility value of diagrams in the teaching and learning of geometry”	G. Sunzuma <i>et al.</i>	ERIC
6	“Reflections from the lesson study for the development of techno-pedagogical competencies in teaching fractal Geometry”	A. Yildiz and S. Baltac	ERIC
7	“Formation and development of mathematical literacy in the context of evaluative – Study tasks of PISA”	D. Nurgaby1, B. Satkulov and A. Kagazbayeva	ERIC
8	“Mathematics mediational means and learner centeredness: insights from ‘traditional’ malawian secondary school geometry lessons”	L. Mwadzaangati, J. Adler and M. Kazima	ERIC
9	“Lesson hiccups during the development of teaching schemes: a novice technology-using mathematics teacher's professional instrumental genesis of dynamic geometry”	G. Bozkurt and C. Uygan	ERIC
10	“Examination of technology acceptance and TPACK competencies of mathematics teachers who are involved in distance education practices during the pandemic process”	O. D. Kiyici and F. T. Dikkartin Övez	ERIC
11	“A heuristic approach to assess change in mathematical knowledge for teaching geometry after a practice-based professional learning intervention”	P. G. Herbst, I. Ko and A. Milewski	ERIC
12	“Impacting teachers' understanding of geometric similarity: results from field testing of the learning and teaching geometry professional development materials”	N. M. Seago <i>et al.</i>	ERIC
13	“We won't know it since we don't teach it: Interactions between teachers' knowledge and practice”	K. Brodie and R. Sanni	ERIC
14	“The teacher's perspective on the separation between conjecturing and proving in high school geometry classrooms”	W. R. Aaron and P. G. Herbst	ERIC
15	“‘Can this happen only in Japan?': mathematics teachers reflect on a videotaped lesson in a cross-cultural context”	G. Schwarts and R. Karsenty	ERIC
16	“Proof transcription in high school geometry: a study of what teachers recognize as normative when students present proofs at the board”	J. K. Dimmel and P. G. Herbst	ERIC
17	“Pivotal teaching moments in technology-intensive secondary geometry classrooms”	C. Cayton <i>et al.</i>	ERIC
18	“How can teaching simulations help us study at scale the tensions mathematics teachers have to manage when considering policy recommendations?”	P. G. Herbst <i>et al.</i>	ERIC
19	“Fostering empirical examination after proof construction in secondary school geometry”	K. Komatsu	ERIC
20	“The role of theory building in the teaching of secondary geometry”	M. Weiss and P. G. Herbst	ERIC
21	“Will teachers create opportunities for discussion when teaching proof in a geometry classroom?”	A. Erickson and P. G. Herbst	ERIC
22	“Teachers' involvement in designing MERLO items: Boundary crossing”	O. Robutti, T. Prodromou and G. Aldon	ERIC
23	“Influences of technology integrated professional development course on mathematics teachers”	U. Kul	ERIC
24	“Using theories and research to analyze a case: learning about example use”	D. Tirosh <i>et al.</i>	ERIC
25	“Enacting core practices of effective mathematics pedagogy with GeoGebra”	I. Benning	ERIC
26	“Using representations of practice to elicit mathematics teachers' tacit knowledge of practice: a comparison of responses to animations and videos”	P. G. Herbst and K. W. Kosko	ERIC
27	“Secondary school mathematics teachers' and students' views on computer assisted mathematics instruction in Turkey: Mathematica example”	M. A. Ardiç and T. Isleyen	ERIC
28	“The use of carefully planned board work to support the productive discussion of multiple student responses in a Japanese problem-solving lesson”	F. Baldry <i>et al.</i>	ERIC
29	“Complementing mathematics teachers' horizon content knowledge with an elementary-on-advanced aspect”	Y. Cho and F. Tee	ERIC
30	“Analysing the relationship between the problem-solving-related beliefs, competence and teaching of three cypriot primary teachers”	P. Andrews and C. Xenofontos	ERIC

Source: Authors' own elaboration.

The articles obtained were analyzed vertically, considering the following units of analysis: (1) year of publication; (2) country where the research was conducted; (3) theoretical approaches; (4) cultural tool; (5) geometry content; (6) level of education; (7) research methodology; and (8) data collection instruments. To identify these aspects, the following were observed: the abstract; the research questions; the objective(s); the main theoretical references; the methodological procedures, focusing on the participants and the research context, and the instruments and procedures for data collection and analysis; and the main results and considerations of each of the articles in Table 1. Subsequently, the articles were analyzed horizontally, observing the aforementioned units of analysis in parallel across all articles. Due to the large number of articles, this study will be limited to presenting the results of the horizontal analysis, shown below.

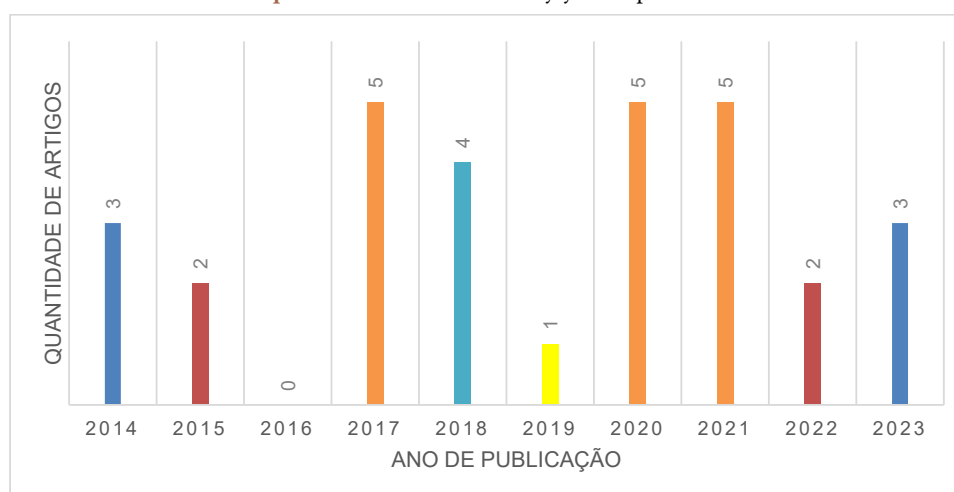
4. Results

This section presents the considerations regarding the horizontal analysis of each of the units of analysis described in Section 3.

4.1 Year of publication

Graph 1 presents the number of articles by year of publication.

Graph 1 – Number of articles by year of publication



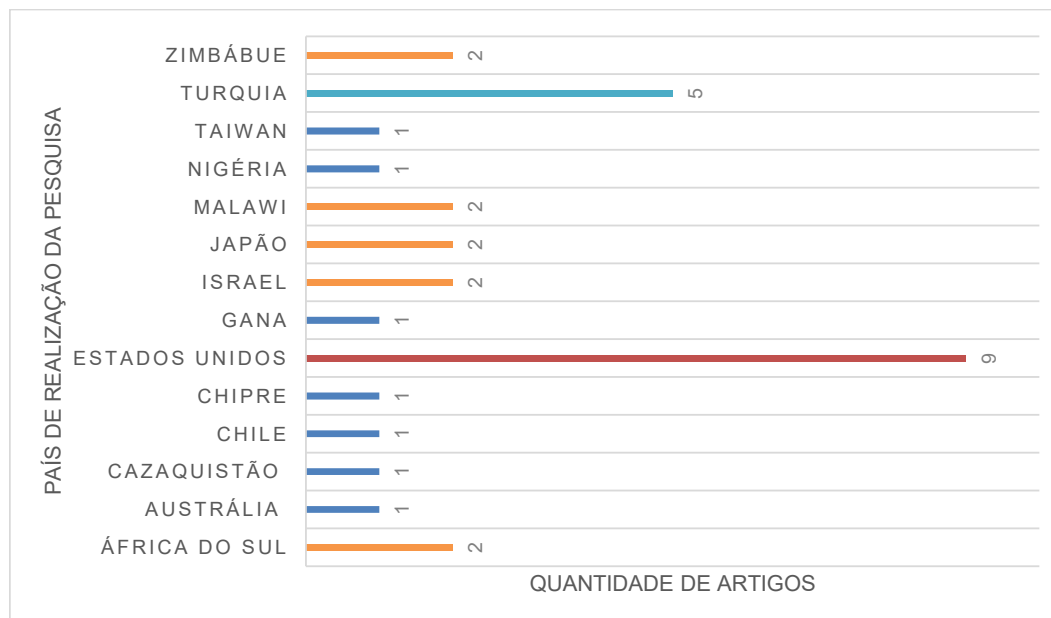
Source: research data

Graph 1 indicates that more than 80% of the articles analyzed were published after 2017 and two-thirds of the articles were published between 2017 and 2021. These data point to growth in research on teachers' pedagogical practice with a focus on teaching performance. The decrease in publications in 2022 and 2023 may reflect the Covid-19 pandemic, which occurred in 2020 and 2021 and had an impact on the development of research in the most diverse areas. However, further studies are needed to confirm this inference. Even so, based on the period analyzed, it is possible to identify signs of an increase in research on the pedagogical practice of the teacher who teaches geometry over the last 8 years.

4.2 Country where the research was conducted

Graph 2 indicates the number of studies conducted by country.

Graph 2 – Number of articles by country where the research was conducted³



Source: research data

Graph 2 points to a variety of countries in which the studies were conducted and shows that 60% of them took place in Asia and Africa. Although these data indicate a dissemination of research on the pedagogical practice of teachers who teach geometry across several countries, the United States stands out as the country where the largest number of studies was conducted (9). There is also a small number of studies in Europe, as well as in South America, with only 1 study in Chile. Although such incidences result from the databases used in this literature review, even with the inclusion of national and Latin American databases, the absence of studies in Brazil highlights the need to develop research with such a focus in the national context.

4.3 Theoretical approaches

This section presents the theoretical approaches that the authors used to ground teachers' pedagogical practice in their studies. The theoretical approaches in the articles were identified predominantly through the objectives presented by the authors and complemented by analysis of the theoretical references, results, discussions, and considerations presented. Teacher thinking approaches were considered to be those emphasizing knowledge, competencies, attitudes, and concept mediation carried out by teachers; technological mediation approaches, those that highlight the role of digital technologies in teaching processes; contextual approaches, those in which attention to teaching contexts and to subjective aspects of teachers' pedagogical practice predominates; and post-contextual approaches, those that not only considered the context of teachers' pedagogical practice but also offered in-depth problematizations of the aspects observed. The theoretical approaches in each category, as well as the articles that used them, are presented in Table 2.

³The research reported in article 13 of Table 1 was conducted in two countries: South Africa and Nigeria.

Table 2 – Theoretical approaches that ground teachers' pedagogical practice

Theoretical Approach	Main Reference/Theoretical Model	Authors of the Theoretical Framework	Articles
Teacher Thinking	MTSK – Mathematics Teachers' Specialized Knowledge	J. Carrillo <i>et al.</i>	1
	Ethnomathematics	U. D'Ambrosio	3
	MTF – Mathematics Teaching Framework	J. Adler	4
	Diagrams	H. Purchase / K. Komatsu	5, 19
	Problem Solving	W. T. Gowers / A. Takahashi	7, 20, 28
	MDI – Mathematics Discourse in Instruction	J. Adler and E. Ronda	8
	MKT – Mathematical Knowledge for Teaching	D. Ball <i>et al.</i>	11, 12
	PCK – Pedagogical Content Knowledge	L. Shulman	13
	Instructional Situations	P. Herbst <i>et al.</i>	14, 16, 18
	Discussions	M. C. O'Connor / M. K. Stein and M. Smith	21
	Beliefs	P. Ernest / J. Skott	23, 30
	Use of Examples and Counterexamples	O. Zaslavsky and I. Zodik / P. Tsamir <i>et al.</i>	24
	Effective Mathematics Pedagogy	G. Anthony and M. Walshaw	25
	Tacit Knowledge for Teaching	P. Grossman <i>et al.</i> / P. Herbst	26
	HCK – Horizon Content Knowledge	D. Ball <i>et al.</i>	29
Technological Mediation	Visualization Skills	A. Arcavi / N. Presmeg	2
	TPACK – Technological Pedagogical Content Knowledge	P. Mishra and M. Koehler	6, 10
	Professional Instrumental Genesis	M. Haspekian	9
	Pivotal Teaching Moments	S. L. Stockero and L. R. Van Zoest	17
	CAMI – Computer Assisted Mathematics Instruction	B. Arslan	27
Contextual	Reflections on One's Own Practice	T. E. Ricks	15
	MERLO – Meaning Equivalence Reusable Learning Objects	M. Etkind <i>et al.</i>	22
Post-Contextual	—	—	—

Source: research data.

Table 2 shows the theoretical approaches used in the articles analyzed, and 22 distinct theoretical references or models were identified across the 30 articles. It was also possible to identify that teacher thinking approaches covered the largest number of articles. Of the 30 studies analyzed, 22 had as their object of study the way teachers apply their various types of knowledge in the classroom, their attitudes toward the use of certain cultural tools, the way they explore certain conceptions and teaching methodologies, and how such use is reflected in more effective (or not) student learning of geometry concepts.

Following teacher thinking approaches are technological mediation approaches, with six articles, and contextual approaches, with two articles. None of the articles analyzed used post-contextual approaches. The low number of articles emphasizing teaching contexts and their influence on teachers' pedagogical practice is noteworthy. In contrast are the articles focused on the teacher's actions, in which the mastery, or lack thereof, of a technique, concept, methodology, content knowledge, or pedagogical knowledge predominates. The absence of articles that not only address such contexts but also problematize them stands out. Teachers' personal and individual elements are constituted both by characteristics that emanate from the collective—for example, the cultural aspects of the environment in which they are situated—and by particular characteristics, such as each teacher's personality. Thus, the need for research addressing these elements, which have repercussions on teaching practice when teaching geometry, is emphasized.

4.4 Cultural tools

Cultural tools were identified in the articles by observing the means proposed by researchers to research participants in order to set teachers' pedagogical practice in motion and bring out aspects related to the research questions. For example, Cho and Tee (2018) used task solving as a cultural tool to highlight and analyze aspects of the participating teachers' HCK. In the articles analyzed, 18 different main cultural tools were identified. These tools were categorized into 4 groups, according to their common characteristics: (1) *Validation Tasks and Strategies*: includes the design, analysis, and solving of tasks in varied formats, as well as the use of demonstration and proof techniques; (2) *Teaching Resources*: encompasses the use of resources such as the physical structures of the classroom, manipulative materials, and technological tools; (3) *Discussions*: focuses on the emergence of elements through the analysis of discussions among the teachers participating in the research, which may take varied formats; (4) *Analysis of Teachers' Pedagogical Practice*: includes strategies for analyzing teaching performance, through in-person observation, video analysis, simulations, and lesson planning.

Table 3 presents these categories, each of the tools that composed them, and the articles that used them.

Table 3 – Cultural tool used to highlight teachers' pedagogical practice

Category	Cultural Tool	Articles
Validation Tasks and Strategies	Demonstrations and Proofs	1, 8, 14, 16, 19
	Problem Solving	7, 30
	Design-Based Research for Task Design	22
	Task Solving	23, 29
	Task Analysis	24
Teaching Resources	Digital Technologies	2, 9, 10, 17, 27
	Diagrams	5
	Blackboard	28
Discussions	Focus Groups	3
	Teaching Landscapes	13, 20
	Dialogues Among Teachers	26
Analysis of Teachers' Pedagogical Practice	Lesson Study	4, 6
	Story Circles	11
	Lesson Videos	12, 15
	Lesson Simulations	18
	Landscapes of Investigation	21
	Lesson Plans and Observations	25

Source: research data.

Table 3 indicates that 11 of the 30 articles analyzed used Validation Tasks and Strategies as a cultural tool to address their objectives and materialize teachers' pedagogical practice, with demonstrations and proofs used by 5 of the articles that composed this literature review. The second most used cultural tool was the Analysis of Teachers' Pedagogical Practice, identified in 8 articles, followed by Teaching Resources (with emphasis on the use of technologies), present in 7 articles. Finally, the cultural tool least used by the authors was Discussions among teachers, present in 4 of the 30 articles analyzed. Thus, there is a lack of studies that use teachers' discussions and reflections as a cultural tool to address their objectives. The need for research that values teachers' discussions and accounts, such as their narratives (which were not used in any of the articles analyzed), is emphasized, since through such means countless elements, composed of a wealth of information, can emerge that may bring more credible aspects of the reality of everyday school life.

4.5 Geometry content

Among the articles that composed this literature review, a variety of geometry content was identified. This content was grouped into: (1) *Proportions, Similarities, and Congruences*: deals with figures or elements that present these relationships; (2) *Angles*: contains various relationships and theorems related to angles, in varied situations; (3) *Trigonometry*: addresses various trigonometric relationships; (4) *Plane and Spatial Geometry*: encompasses concepts and definitions of the elements that compose these objects of knowledge, as well as the calculation of perimeters, areas, and volumes; (5) *Fractal Geometry*: explores concepts of pattern repetition, present or not in nature, extrapolating the

concepts of Euclidean Geometry; (6) *Not Specified*: articles that did not specify the geometry content addressed.

Table 4 presents the categories and the specific content addressed in each of the articles.

Table 4 – Geometric knowledge

Category	Content	Articles
Proportions, Similarities, and Congruences	Proportion and Similarity of Triangles	1, 16
	Similarity Between Polygons	12
	Congruence of Triangles	18, 19
	Thales' Theorem	24
Angles	Central Angle Theorem	2
	Angles Inscribed in a Circle	8
	Angle Bisectors	14, 17
	Angles Formed by Parallel Lines Cut by a Transversal	28
Trigonometry	Properties of Triangles	4
	Trigonometry in the Right Triangle	7
	Trigonometric Ratios	11
Plane and Spatial Geometry	Quadrilaterals	9
	Plane and Spatial Geometry	13, 20
	Perimeters and Areas	15, 22, 25, 30
	Parallelograms	26
	Volume	29
Fractal Geometry	Fractal Geometry	6
Not Specified	—	3, 5, 10, 21, 23, 27

Source: research data.

According to Table 4, it is possible to identify that the geometry content addressed in the articles showed variety, highlighting the wide possibilities for approaching and applying it. This finding underscores the importance of addressing such content in the classroom and of continuing to develop research involving these themes. The most frequent content was related to Plane and Spatial Geometry (nine articles), with emphasis on the calculation of perimeters and areas. Thus, it can be inferred that, although this object of knowledge is usually underestimated in teaching practice in relation to other mathematical content, its occurrence in research themes indicates the importance of addressing it in the classroom with due relevance. Therefore, greater attention should be directed to teachers' professional knowledge about it, as well as to the planning, selection, and design of tasks and the implementation of the concepts that compose it.

Even though limited to a single article, there is a study related to Fractal Geometry. Although rarely addressed, this object of knowledge develops students' reasoning skills, since it breaks with the already consolidated patterns of Euclidean Geometry and proposes new ways of understanding geometry and relating it to the real world—for example, by exploring the presence of fractal patterns

in nature. In this sense, technological tools can contribute significantly to the understanding of Fractal Geometry and to the exploration of contrasts between Euclidean and Non-Euclidean Geometry. Thus, the need for research addressing this content is emphasized, expanding students' knowledge of the possibilities of geometry.

4.6 Level of education

Of the 30 articles analyzed, 3 (3, 20 and 23) did not specify the level of education at which their research was conducted; and 5 (10, 12, 13, 21 and 22) addressed both the final years of Elementary School and High School. Seven of them (4, 6, 9, 15, 19, 28 and 30) focused only on the final years of Elementary School; and the remaining 15 articles concentrated on High School. These data may represent a growing importance of investigating pedagogical practices for teaching geometry at more advanced levels of education, which may indicate that geometry is gaining relevance in these spaces in relation to other mathematical content. This observation does not exclude the fact that research should continue to investigate the pedagogical practice of teachers who teach geometry in the final years of Elementary School, since grounding such content at this level of education is essential for its deepening in subsequent levels of education.

4.7 Research methodology

Since these are studies on teachers' pedagogical practice, the expectation was that the methodology used would be qualitative, given that its conceptions are in line with research that takes the subjective aspects of human beings as its object of study. However, although 23 of the 30 articles analyzed met these expectations, 5 articles (articles 10, 11, 12, 18 and 26) used quantitative methodology, measuring teachers' professional knowledge through statistical resources and analyses. In addition, 2 articles (3 and 5) used mixed methodology. This finding indicates the emergence of new ways of observing and analyzing teachers' pedagogical practice and, consequently, of proposing new possibilities to contribute to it. However, the need to define adequate procedures and resources for this analysis is emphasized, since discrepancies may occur in attempts to measure and systematize aspects that may be subjective.

4.8 Data collection instruments

In the 30 articles analyzed, 10 distinct data collection instruments were identified, and most researchers used 2 or more of them. These instruments are presented in Table 5.

According to Table 5, the 3 most used data collection instruments were video, interviews, and questionnaires, identified in 12, 11, and 10 articles, respectively. This predominance is justified by the fact that these instruments can provide a considerable amount of data, which can be revisited countless times if necessary. In contrast, the least used instruments were lesson plans, task solving, and written reflections, used in 3, 1, and 1 articles, respectively. Lesson plans and task solving may not have been widely used because they are associated with more specific research questions and objectives. However, teachers' accounts could have been used more—just like discussions as a cultural tool used to highlight teachers' pedagogical practice—since they provide relevant and rich information about everyday school life.

Table 5 – Data collection instruments

Article	Audio	Video	Interviews	Discussions	Questionnaires	Lesson Plans	Task Solving	Observations	Field Notes	Written Reflections
1	x	x	x							
2	x	x	x							
3				x	x					
4	x	x		x		x				
5			x		x					
6	x		x							
7							x			
8		x								
9			x					x	x	
10					x					
11					x					
12					x					
13			x							
14	x	x								
15	x	x		x					x	x
16					x					
17		x						x		
18					x					
19		x						x	x	
20		x								
21					x					
22				x	x					
23			x					x	x	
24					x					
25			x	x		x		x		
26	x	x		x						
27	x		x							
28		x				x			x	
29		x	x					x		
30	x		x					x	x	
TOTAL	9	12	11	6	10	3	1	7	6	1

Source: research data.

Finally, the need to combine two or more data collection instruments is emphasized, so that the information obtained can be complemented and corroborated.

5. Discussion

Table 6 establishes a relationship between the theoretical approaches and the cultural tools used to put into action the pedagogical practice of teachers who teach geometry identified in the articles. To this end, the data described in Table 2 and Table 3 were cross-referenced.

Table 6 – Theoretical approaches and cultural tools used in the articles

		Theoretical Approaches			
		Teacher Thinking	Technological Mediation	Contextual	Post-Contextual
Cultural Tool	Validation Tasks and Strategies	1, 7, 8, 14, 16, 19, 23, 24, 29, 30	–	22	–
	Technologies, Diagrams, etc.	5, 28	2, 9, 10, 17, 27	–	–
	Focus Groups, Landscapes, etc.	3, 13, 20, 26	–	–	–
	Lesson Study, Videos, etc.	4, 11, 12, 18, 21, 25	6	15	–

Source: research data.

According to Table 6, of the 30 articles that composed the literature review, 22 used teacher thinking theoretical approaches. In 12 of them, the cultural tools highlighted were Validation Tasks and Strategies and Teaching Resources, that is, the way teachers use such tools in their classes. In these articles, the teacher's subjectivity, individual aspects, and teaching contexts were practically disregarded. Thus, theoretical approaches, cultural tools, and agents were analyzed in a disconnected manner, mischaracterizing the conception of mediated action proposed by Wertsch (1991, 1998).

Table 6 also makes it possible to identify that 8 of the 30 articles analyzed highlighted the Analysis of Teachers' Pedagogical Practice as a cultural tool. However, in 7 of them, the theoretical approaches used to understand this practice were oriented toward teacher thinking and technological mediation, as in the 4 articles that highlighted Discussions as a cultural tool. These aspects are relevant to teachers' work and were even identified as objects of study in a significant number of studies. However, it is worth noting that intentionality, teachers' values, and students' specific demands—which, according to Silva and Silva (2022), also compose teachers' pedagogical practice—were left in the background in most of the studies. It is also emphasized that, according to Wertsch (1998), the relationship between the agent and a given cultural tool is governed by cultural, institutional, and historical aspects. Therefore, when analyzing the relationship between a given agent and a cultural tool without considering such aspects, the analysis becomes superficial and incomplete.

Table 6 shows the low occurrence of contextual theoretical approaches and the absence of Teaching Resources and Discussions as cultural tools in such approaches. The absence of studies using post-contextual approaches to discuss the pedagogical practice of teachers who teach geometry is also

emphasized. Thus, there is room for research that uses these approaches and tools, especially Discussions, since they can be a promoting resource for highlighting subjective aspects of teachers' pedagogical practice.

Another point of attention is the use of quantitative methodology to analyze teachers' pedagogical practice in 5 of the 30 articles analyzed. Although these procedures are legitimate and necessary in some situations, such occurrence also evidences a dissociated and limited analysis of the elements that compose the mediated action. Based on the analyses presented, the research question is revisited: *how are theoretical approaches used to guide studies on the mediated action that constitutes the pedagogical practice of teachers who teach geometry?*

Theoretical approaches are used to guide studies on the pedagogical practice of the teacher who teaches geometry mostly in ways that emphasize teachers' knowledge—of content, pedagogical, methodological, among others—and the way such knowledge is operationalized in the classroom. The high number of studies that used questionnaires and interviews as data collection instruments, the presence of quantitative studies, and the low number of studies with contextual and post-contextual approaches corroborate this inference. The sociocultural aspects and the individualities of teachers and students are considered supporting actors in most of the articles analyzed.

For the pedagogical practice of teachers who teach geometry to be fully constituted as a mediated action, its objective and subjective aspects must be considered on the same level, with neither standing out over the other. The same should hold for the teacher's relationship with the cultural tools they use, given that an emphasis on objective aspects and a disregard for subjective ones make the analysis and understanding of the mediated action superficial and incomplete.

6. Final considerations

This article focused on a systematic literature review, aiming to address the following objective: *to identify and describe how the pedagogical practice of teachers who teach geometry is treated in scientific studies*. After analyzing the 30 articles that composed the review, it was possible to identify 3 theoretical approaches, evidenced by 18 distinct cultural tools, applied to varied geometry content and directed at different levels of education.

The low occurrence of articles focusing on the teacher's subjective aspects deserves emphasis. This finding suggests that teaching knowledge and classroom performance are seen as more relevant than teachers' personal aspects, and that the latter cannot or should not interfere with their practice, when in reality it is precisely these aspects that will be responsible for relating theoretical and practical elements through intentionality, so that pedagogical practice is constituted as a truly mediated action.

The cultural tools used in such theoretical approaches, as well as the data collection instruments, corroborate this inference. The least used tools, as well as the least used data collection instruments, were related to discussions and reflections among teachers. In addition, the absence of narratives as a data collection instrument is emphasized.

Regarding the countries where the research was conducted, the low occurrence in South American countries and the absence of research on this theme in Brazil stand out. Even though the low occurrence is justified by the descriptors and databases used in this literature review, which constitutes a limitation of the procedure, there is room for research of this nature in the Brazilian teaching context. Other criteria for the selection and analysis of the articles could result in different findings.

A variety of geometry content addressed in the studies was identified. This variety highlights the versatility of such constructs and the importance not only of understanding them, but also of their relationship with other thematic units of mathematics and their application in those other contents.

Returning to the research question—*how are theoretical approaches used to guide studies on the mediated action that constitutes the pedagogical practice of teachers who teach geometry?*—it is emphasized that the mediated action that constitutes the pedagogical practice of the teacher who teaches geometry cannot be approached in a fragmented way that disregards some of its elements, such as the teacher's subjectivity inherent in the teaching process, resulting in a superficial and incomplete analysis. However, this was the approach taken by most of the articles that composed this literature review.

In light of the results, there is a clear need for research that addresses teachers' pedagogical practice contextually and post-contextually, integrating teachers' experiences and subjectivity on the same level as teacher thinking and technological mediation. In the Brazilian context, this agenda of future research will allow a more central understanding of the mediated action between agent and cultural tool and, further, allow such research to effectively be reflected in teachers' classroom practice.

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Not applicable / These research data have not been published in the data repository; however, the authors are committed to sharing them if the reader is interested.

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