Revista Colombiana de Educación N. 101 Año 2026
ISSN 0120-3916 / e-ISSN: 2323-0134
DOI: https://doi.org/10.17227/rce.num101-20490
Universidad Pedagógica Nacional, Colombia

Trends in Geometry Teachers' Professional Knowledge in Elementary, Middle and High School Education: A Systematic Literature Review

Received: December 13, 2023
Reviewed: January 30, 2025
Published: July 1, 2026

Claudia Lorena Mora-Pérez*
Mauro Rivas-Olivo**

Type: Review article

Abstract

On this article, a descriptive and systematic literature review is presented focused on the geometry teachers' professional knowledge at the elementary (ages 6 to 10), middle (ages 11 to 14) and high school (ages 15 to 18) levels, published in academic-scientific research journals. This review brings together information from articles published in the period between 2012 and 2022. The systematic search, which is carried out and described in detail, resulted in the selection of 40 studies. Through a comprehensive analysis of this corpus, several predominant trends were identified, such as the types of participants, the geometric content treated, teacher's knowledge model used and level of teaching to which the studies pertain. At the same time, the most relevant results with in-service (active) teachers and from 9 of the 40 studies are presented. The results indicate that implemented with teachers in initial training are the predominant trend. In terms of geometric content, the study of basic two-dimensional objects predominates, particularly within the context of elementary education. Furthermore,the Mathematical Knowledge for Teaching (MKT) framework emerged as the predominant theoretical model employed across the selected studies.. Regarding the development of professional knowledge, studies conducted with in-service teachers highlight the need to enhance teachers' professional training in both geometry content and its teaching methods (pedagogy).

Keywords

middle school teachers; high school teachers; in-service teacher education; mathematics education; geometry

* Master's Degree in Mathematics Education. Technological University of Pereira. claudialorena.mora@utp.edu.co
** PhD in Mathematics Education (Didactics of Mathematics). University of Granada. maurorivas@ugr.es

Tendências do conhecimento profissional de professores de geometria do ensino fundamental e médio: uma revisão sistemática da literatura

Resumo

Neste artigo, apresentamos uma revisão sistemática descritiva da literatura sobre os conhecimentos do professor de geometria nos níveis fundamental (6-14 anos) e médio (15-18 anos), publicados em revistas de pesquisa acadêmico-científica. Esta revisão reúne informações de artigos publicados no período entre 2012 e 2022. A pesquisa sistemática, que é realizada e descrita em detalhe, permitiu a seleção de 40 estudos, nos quais se identificam tendências sobre os tipos de participantes, conteúdos geométricos abordados, modelo de conhecimento do professor utilizado e nível de ensino a que se referem. São também apresentados os resultados mais relevantes de nove estudos (dos 40) com professores em serviço. Os resultados indicam que há uma predominância de estudos realizados com professores em formação inicial; em termos de conteúdos geométricos, predomina o estudo de objectos bidimensionais básicos; em termos de nível de ensino, predomina o ensino básico; e o modelo mais utilizado é o Conhecimento Matemático para o Ensino (*Mathematical Knowledge for Teaching*). Quanto ao desenvolvimento do conhecimento profissional, de acordo com os resultados dos estudos realizados com professores em serviço, estes tendem a sublinhar a necessidade de melhorar a formação profissional dos professores em conteúdos e didática da geometria.

Palavras chave

professores do ensino médio; formação continuada de professores; educação matemática; geometria

Tendencias sobre el conocimiento profesional de los profesores de geometría, en la educación básica y media: una revisión sistemática de la literatura

Resumen

En este artículo, presentamos una revisión sistemática descriptiva de la literatura sobre el conocimiento del profesor de geometría en los niveles de educación básica (6-14 años) y media (15-18 años), que se encuentran publicados en revistas de investigación académica-científica. Esta revisión reúne la información de los artículos publicados entre los años 2012 y 2022. La búsqueda sistemática descrita con detalle permitió la selección de cuarenta estudios, en los que se identifican tendencias sobre los tipos de participantes, contenido geométrico tratado, modelo del conocimiento del profesor utilizado y nivel de enseñanza al que se refieren. Asimismo, se presentan los resultados más relevantes de nueve estudios (de los cuarenta) con profesores en servicio. Los resultados indican que hay un predominio de los trabajos con profesores en formación inicial. En cuanto al contenido geométrico, predomina el estudio de objetos bidimensionales básicos; además, en lo relativo al nivel educativo destaca el de educación primaria. Se identificó también que el modelo más utilizado es el Conocimiento Matemático para la Enseñanza (Mathematical Knowledge for Teaching). Sobre el desarrollo del conocimiento profesional, según los resultados de los estudios realizados con profesores en servicio, se encuentra que tienden a subrayar la necesidad de mejorar su formación profesional en el contenido sobre geometría y en su didáctica.

Palabras clave:

profesores de educación básica; profesores de educación media; formación docente en servicio; educación matemática; geometría

To cite this article:

Mora-Pérez, C. L. y Rivas-Olivo, M. (2026). Trends in Geometry Teachers' Professional Knowledge in Elementary, Middle and High School Education: A Systematic Literature Review. *Revista Colombiana de Educación,* (101), e20490, https://doi.org//10.17227/rce.num101-20490

Introduction

The study of teacher knowledge has been, since its initial characterizations (Shulman, 1986), an area of paramount relevance in the educational sciences, particularly in mathematics education. The development of this kind of knowledge has generated increasing interest in teacher training and research circles (Aparicio-Landa et al., 2021; Montes et al., 2022; Ponte & Chapman, 2006). Given the progressive growth of studies in this field (Huang et al., 2020), it becomes increasingly relevant to identify key trends, needs, and significant findings. Accordingly, this paper reports findings from a descriptive systematic review (Newman & Gough, 2020; Paré et al., 2015) analyzing articles published in multiple information systems that: 1) index high-impact journals in the scientific-academic field (*Web of Science*, *Scopus*) (Zhu & Liu, 2020), 2) devoted exclusively to educational research (ERIC: *Education Resources Information Center*) (Robbins, 2001), and 3) are widely disseminated (*Google Scholar*) (Martín-Martín et al., 2018). These information systems are used to access articles addressing the topic of mathematics teacher knowledge, which –when specifically concerning geometric content, its teaching and learning– makes the continued systematization of findings and methods particularly crucial (Jones & Tzezaki, 2016).

Recognizing that the theme constitutes a field of study involving the interaction of diverse elements (e.g., Ponte & Chapman, 2006) it is necessary to establish specific elements of interest. In this case, it is pertinent to study, within this theme, aspects such as the types of participants, basic and secondary school geometry as the mathematical content studied, the teacher knowledge model used, and the educational level being addressed. In this context, the following question arises: What trends do these aspects exhibit in the academic-scientific literature –specifically in research articles– concerning the professional knowledge required by mathematics teachers for the instruction of geometry? To address this question, it is considered relevant to address other inquires: What trends emerge in this body of work regarding the types of participants – preservice and in-service mathematics teachers – in relation to the geometry teaching? What trends are presented in this research production regarding the use of models or theories that have been used to study mathematics teachers' knowledge, the geometric content addressed, and the educational level of the content, with both preservice and in-service teachers? And what trends emerge from the research findings within this body of work regarding mathematics teachers' professional knowledge, focusing on in-service teachers?

Building on these questions, the literature review concerning this topic pursues two objectives:

Objective 1 (O1). To discern trends in studies of geometry teachers' knowledge, analyzing participant types along three dimensions: the geometric content covered, the theoretical frameworks employed, and the targeted educational stages.

Objective 2 (O2). To examine emerging trends and scholarly progress in studies addressing the professional knowledge development of geometry teachers in education levels (elementary, middle, and high school).

Pursuant to these dual objectives, the research is structured in two components. The initial component, corresponding to objective (O1), employs a holistic perspective examining three critical dimensions of geometry teacher knowledge – content knowledge, theoretical frameworks, and instructional levels – applicable to both preservice and in-service teachers. The second part addresses objective 2 (O2) by focusing specifically on studies involving in-service teachers. This approach is grounded in the understanding that teachers' professional knowledge develops precisely through their active practice. As Climent (2002) defines it, professional teacher knowledge "...comprises the totality of knowledge and experiences that teachers possess and draw upon in their teaching practice..." (pp. 52-53).

Research Theme and Analytical Categories

Following the defined objectives, a research theme (T) and five analytical categories (C1-C5) are defined. The primary theme, Geometry Teacher Knowledge (T), is operationalized through the following categories: C1: Participant Type; C2: Geometric Content (spanning elementary, middle, and high school curricula); C3: Teacher Knowledge Model; C4: Educational Level; and C5: Findings from In-service Teachers. It should be noted that categories C1-C4 align with O1, while category C5 corresponds to O2. Figure 1 schematically displays relationships between the main theme (T) and these categories. The following paragraphs provide a comprehensive characterization of each category to facilitate the analysis.

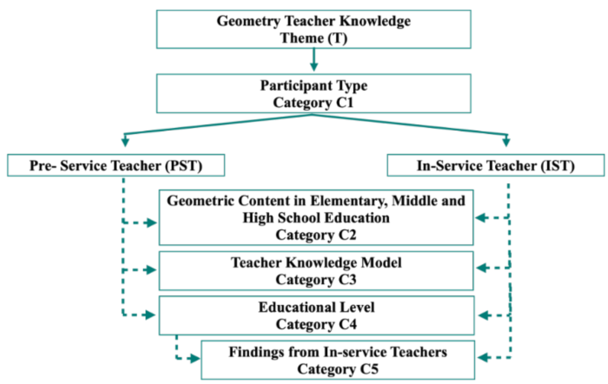
Geometry Teacher Knowledge (T)

Geometry teacher knowledge is interpreted as the common idea that emerges when considering different approaches aimed at its study (pedagogical content knowledge, mathematical knowledge for teaching, didactic-mathematical knowledge, specialized knowledge, etc.) proposed by various researchers: Shulman (1986); Ball (2000); Schoenfeld & Kilpatrick (2008); Carrillo et al.

(2013); Pino-Fan & Godino (2015), with the mathematical content being that of geometry. Knowledge is defined as the broad network of concepts, procedures, representations, properties, reasoning methods, and intellectual abilities that individuals possess or that constitute part of a society's historical and cultural heritage. It can be acquired through individual practice or social interaction across diverse contexts (Godino, 2009). Specifically, and for the purposes of developing the second part of this review, the geometry teachers' professional knowledge is interpreted in the terms outlined by Climent (2002), as previously referenced.

Figure 1

Research Theme, Analytical Categories and Interrelations.



Note. Own elaboration.

Participant Type (C1)

Given that the focus of this review revolves around teacher knowledge, two participant types (or subcategories) emerge: Pre-Service Teachers and In-Service Teachers. Special attention will be given to the latter, as they actively apply such knowledge in their everyday teaching practice (Climent, 2002).

Geometric Content in Elementary, Middle and High School Education (C2)

"Geometric Content in Elementary, Middle and High School Education" is interpreted based on geometric content for these grade levels, as established in the Colombian Ministry of Education's curriculum (MEN, 2006). The Colombian educational curriculum will serve as reference, given its similar design and geometric content to curricula commonly implemented in other countries. Table 1 lists the reference geometric contents.

Table 1

Geometry Curriculum Content in Elementary – Middle school (ages 6 to 14) and High school (ages 15 to 18)

Contents		
Elementary School (1º a 5º)	Middle School (6º a 9º)	High School (10º a 11º)
2D objects	3D objects	Properties of conic sections
3D objects	Longitudinal and transverse sections of 3D objects.	Cartesian and alternative coordinate systems.
Horizontality, verticality, parallelism, and perpendicularity.	Polygons	Curves and conic sections.
Translations and rotations of a figure.	Rigid transformations and homotheties.	Geometric properties of conic sections.
Symmetries	Similar and congruent figures.	Trigonometric relations and functions.
Similar and congruent figures.	Objects in Cartesian and geographic representation systems.	
Direction, distance, and position in space.	Fundamental theorems: Pythagorean and Thales.	
Angles	Congruent and similar triangles.	
Coordinate systems.		

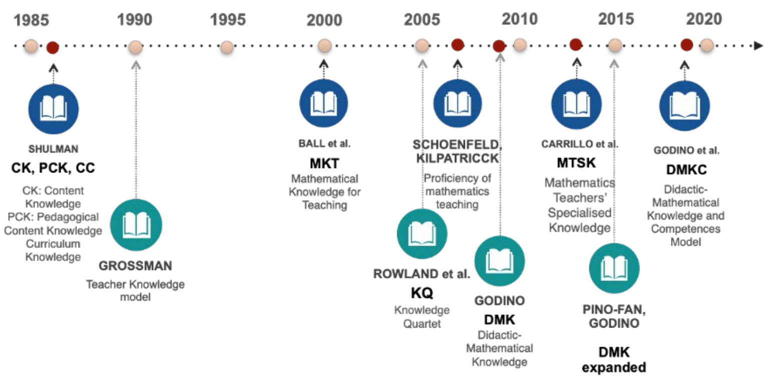
Note. Adapted from the Ministerio de Educación Nacional MEN *(2006).*

Teacher Knowledge Model (C3)

When discussing the studies conducted on teacher knowledge, it is imperative to address the underlying theoretical frameworks that have shaped the field. Figure 2 presents a schematic chronological overview of the most widely used frameworks in mathematics education research. Due to space constraints, we will not discuss specific details here. Readers may consult the references cited in Figure 2 for further information. For this purpose, the following references have been included in the references section: Shulman (1986); Ball (2000); Ball et al. (2001); Hill et al. (2008); Rowland et al (2005); Schoenfeld & Kilpatrick (2008); Godino (2009); Carrillo et al. (2013); Pino-Fan & Godino (2015); Godino et al. (2017); as the leading figures in the creation of these models.

Figure 2

Selected Models of Mathematics Teacher Knowledge and Competence.



Note. Own elaboration.

Educational Level (C4)

This category pertains to the standard organizational levels of educational systems. For our purposes, we will adopt the Colombian system as a reference framework, as its age-based structure allows for comparison with systems in other countries. The parameters of interest in this work are elementary school (ages 6 to 10), middle school (ages 11 to 14), and high school (ages 15 to 18).

Findings from In-service Teachers (C5)

The In-Service Teachers Results' section comprises the diverse contributions, discussions, and conclusions derived from the reviewed studies on professional teacher knowledge development. These studies were selected based on the following criteria. The research theme (T) on Geometry Teacher Knowledge, the educational level category (elementary, middle, and high school education), and the subcategory In-Service Teachers.

Methodology

Research Type

This work presents a descriptive qualitive systematic review (Newman & Gough, 2020; Paré et al., 2015) of the literature on geometry teacher knowledge, synthesizing key trends and scholarly contributions to the field. The reviewed articles were published over a ten-year-period (2012-2022), coinciding with the period of most dynamic growth in teacher education research (Huang et al.,

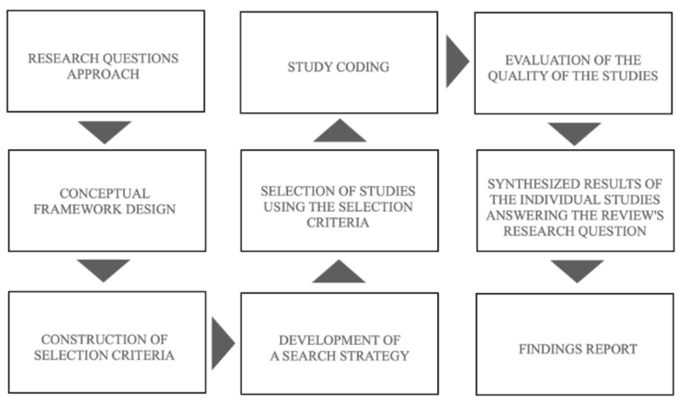
ISSN 0120-3916 / e-ISSN: 2323-0134
DOI: https://doi.org/10.17227/rce.num101-20490
Universidad Pedagógica Nacional, Colombia

2020). Newman and Gough (2020) define a systematic review as a methodologically rigorous and transparent analysis designed to be both reproducible and updatable. In alignment with these criteria, the following section outlines our implementation of their proposed methodology.

Procedure

This study has been implemented according to the schematic presented in Figure 3. At this point in our research process, we were engaged in establishing the selection criteria.

Figure 3
The Systematic Review Process



Note. Adapted from the systematic review process proposed by Newman & Gough (2020, p. 6).

Selection Criteria

The nested selection criteria were applied in the following order:

1) Relevant titles: Selection of articles whose titles contain at least one of the key terms (Table 2, first column). Articles were chosen from the top results of each information system: the first 30 records from databases (Web of Science [WoS], Scopus, ERIC), and the first 50 records from Google Scholar.
2) Relevant works: Selection of articles whose abstract explicitly addresses the study of mathematics teachers' knowledge.
3) Works on the theme (T): Selection of papers that include the term "geometry" (in either English or Spanish: "geometría") in their abstract.
4) Elementary, middle, and high school levels studies: Selection of papers addressing these educational levels.

5) In-service teacher studies: Selection of papers where the participants are in-service teachers.

The application of these criteria during the article selection process is detailed in the subsequent subsection.

Search Strategy Development

The search strategy was developed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009), which utilize a four-phase flow diagram: identification, screening, eligibility, and inclusion. Adhering to this procedure ensures the replicability and future updatability of the research. Figure 4 illustrates the application of this diagram for article selection.

The developed procedure, which includes the application of this diagram, was as follows:

1) Selection of key terms for the search, related to the topic (T) and the categories

   (Table 2, first column).
2) Search for articles, based on the selected key terms, in the information systems (WoS, Scopus, ERIC, Google Scholar) using the following filters: time period (2012-2022), English and Spanish language (since currently, any indexed academic-scientific journal includes an abstract and keywords in English), document type, such as articles, and open access. The search query includes the key terms, separated by commas, along with the specified filters.
3) First selection criterion applied.
4) Second selection criterion applied.
5) Relevant studies were recorded in an Excel spreadsheet containing article title, keywords, and abstract.
6) Removal of duplicate entries.
7) Third selection criterion applied.
8) Fourth selection criterion applied.
9) Descriptive analysis for articles obtained in step eight.
10) Fifth selection criterion applied.
11) Result section analysis for articles selected in step 10.

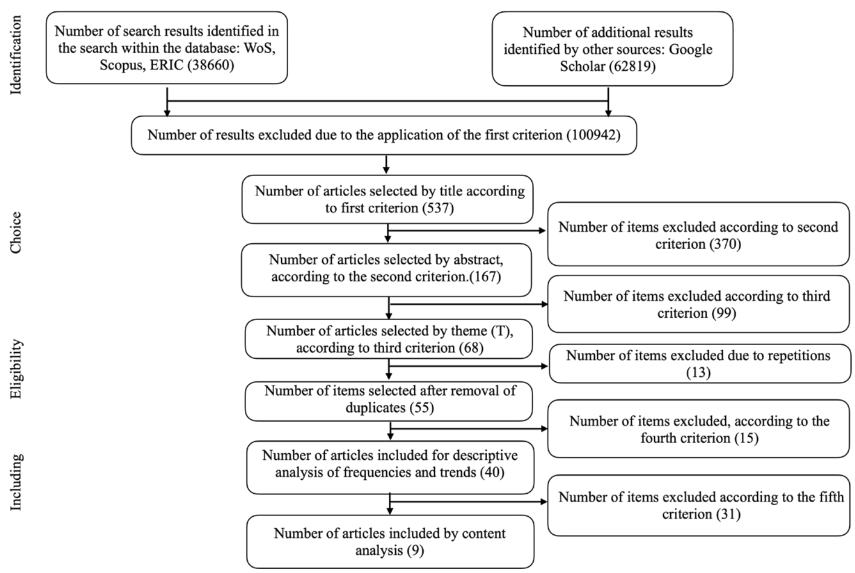
The methodology employed resulted in the identification of empirical research studies.

Findings

Selected studies

The articles selected through the PRISMA procedure (previously outlined and schematized in Figure 4) comprise two sets: 40 articles addressing the core theme (T), a 9-article subset featuring in-service teachers as participants (or partial samples).

Figure 4
Results from each search stage



Note. Adapted from Moher et al. (2009, p. 3).

Study Coding and Quality Appraisal

The article selection process required maintaining a registry to document partial results. Table 2 presents these outcomes. From our Web of Science (WoS) search using 11 keyword groups – 5 in Spanish and 6 in English –, an initial title-based screening of 2 170 retrieved records yielded 81 relevant titles. Subsequent abstract review of these 81 publications allowed us to identify 48 pertinent studies addressing mathematics teachers' knowledge.

Following a similar procedure to the one used in WoS, in Scopus, according to the information shown in Table 2, 41 relevant papers were obtained. Similarly, in ERIC, 32 relevant papers were found. In Google Scholar, the same approach was followed, yielding 46 relevant papers. By adding up the relevant papers found, the total comes to 167 articles.

Next, the information from the chosen articles was coded and recorded in an Excel spreadsheet, including the following data: title, keywords, and abstract. A filter was applied to this record using the key terms "geometría" or "geometry", which resulted in the selection of 40 articles. Based on this selection, specific actions were taken to achieve the proposed objectives, as presented below.

Table 2

Article Selection Following the Described Procedure and the Proposed Variables.

Key words	Search Tools											
	WoS			Scopus			ERIC			Google Scholar		
	# Results	# Relevant titles	# Relevant works	# Results	# Relevant titles	# Relevant works	# Results	# Relevant titles	# Relevant works	# Results	# Relevant titles	# Relevant works
conocimiento, profesor, matemáticas	2	2	2	12	12	12	0	0	0	3010	36	14
knowledge, teacher, mathematics	2073	26	20	3366	13	2	1218	16	14	17800	14	9
conocimiento, profesor, enseñar geometría	0	0	0	0	0	0	0	0	0	283	14	3
knowledge, teacher, geometry teaching	56	24	13	140	18	7	4649	20	15	6280	26	8
conocimiento, profesor en formación inicial, enseñar geometría	0	0	0	0	0	0	0	0	0	183	17	1
knowledge, pre-service teacher, geometry teaching	3	2	1	15	12	7	8463	21	1	2450	24	4
conocimiento, futuro profesor, enseñar geometría	0	0	0	0	0	0	0	0	0	236	14	2
knowledge, training teacher, geometry teaching	21	15	10	29	15	4	7175	21	1	11700	23	3
knowledge, prospective teacher, geometry teaching	5	4	1	13	13	5	5200	14	1	13300	25	2
conocimiento, profesor en ejercicio, enseñar geometría	0	0	0	0	0	0	0	0	0	287	24	0
knowledge, in-service teacher, geometry teaching	10	8	1	26	18	4	6184	20	0	10300	26	0
Total	2170	81	48	3601	101	41	32889	112	32	62819	243	46

Note. Own elaboration.

Synthesized research outcomes

Results Related to Objective O1

To better organize information according to study objectives, Table 3 presents the results for the first subcategory: Participant Type, specifically Pre-service Teachers (PST). Results corresponding to the second subcategory, In-Service Teachers (IST), are displayed in Table 4, whereas Table 5 compiles studies encompassing both subcategories: Pre-Service Teachers (PST) and In-Service Teachers (IST). Figure 5 displays the mathematics teacher knowledge models identified in the reviewed literature, including their acronyms, definitions, and English Spanish-equivalent terminology.

Figure 5
Models Identified in the Study of Teacher Knowledge

Modelo	Significado	Traducción
MTSK	Mathematics Teacher's Specialized Konwledge	Conocimiento Especializado del Profesor de Matemáticas
KQ	Knowledge Quartet	Cuarteto del Conocimiento
TPACK	Technological Pedagogical Content Knowledge	Conocimiento Pedagógico del Contenido Tecnológico
MCK	Mathematical Content Knowledge	Conocimiento del Contenido Matemático
MKT	Mathematical Knowledge for Teaching	Conocimiento Matemático para la Enseñanza
PCK	Pedagogical Content Knowledge	Conocimiento Pedagógico del Contenido
DMK	Didactic-Mathematical Knowledge	Conocimiento Didáctico-Matemático
CK	Content Knowledge	Conocimiento del Contenido

Note. Own elaboration.

Table 3 shows a list of geometric contents for teaching in primary and secondary education, which are the study subject in research with PST. It was identified that a large part refers to primary school level two-dimensional objects.

Table 3
Pre-Service Teachers (PST).

#	Author	Knowledge model	Geometric Content	Educational Level
1	Liñán-García et al. (2021)	MTSK	Euclid's Fifth Postulate	Elementary School
2	Montes et al. (2022)	MTSK	Definition of polygon	Elementary School
3	Gumiero & Pazuch (2021)	KQ	Flat shapes and geometric solids	Middle School
4	Segal et al. (2021)	TPACK	Polygons	Middle School
5	Clemente & Llinares (2015)		Triangles	Elementary School
6	Florio (2022)		Conics: parabola	High School
7	Adelabu & Alex (2022)	MCK	Space and shape, trigonometry	High School
8	Vieira & de Costa-Trindade-Cyrino (2022)		Flat shapes	All levels
9	Yi, et al. (2022)	MKT	Two-dimensional objects	Elementary School
10	Ekawati et al. (2022)	MCK	Space and shape.	All levels
11	Ubah (2021)	PCK	Euclidean Geometry	Middle and High School
12	Castro et al. (2021)	DMK	Euclidean Geometry	Elementary School
13	Hourigan & Leavy (2017)		Euclidean Geometry	Elementary School
14	Aslan-Tutak & Adams (2015)	CK	Quadrilaterals	Elementary School
15	Vodušek & Lipovec (2014)		Square and circumference	Elementary School
16	Tertemiz (2012)		Geometry: basic concepts	Elementary School
17	Erkek & Bostan (2019)		Triangles and circles	Middle School
18	Morales-López (2019)	TPACK	Two-dimensional objects	Middle School
19	Karagöz-Akar (2015)	KQ	Bisector of a triangle	Middle School
20	Eli et al. (2013)	MKT	Two-dimensional and three-dimensional objects	Middle School
21	Nason et al. (2012)	PCK	Symmetry, transformations, three-dimensional objects	Elementary School
22	Zambak & Tyminski. (2020)	MKT	Two-dimensional and three-dimensional objects	Middle School
23	Tefera et al. (2021)	MKT	Two-dimensional and three-dimensional objects	Elementary School
24	Aparicio-Landa et al. (2021)		Area of rectangle	Middle and High School
25	Saralar-Aras & Birgili (2022)	TPACK	Polygons, quadrilaterals, three-dimensional objects	Elementary School
26	Özdemir (2022)		Geometry: Basic concepts	Elementary and Middle School

#	Author	Knowledge model	Geometric Content	Educational Level
27	Bonyah & Larbi (2021)	MKT	Geometric problem solving	Elementary School
28	Özçakir (2019)	TPACK	Tangent circles	Elementary School
29	Niyukuri et al. (2020)	MCK	Triangles, Thales' theorem, quadrilaterals, conics, projections, isometries, homotopies, parallelism.	Middle School
30	Ilhan & Aslaner (2021)		Two-dimensional and three-dimensional objects	All levels
31	Dündar & Gündüz (2017)	PCK	Congruence and similarity in triangles.	Elementary School

Note. Own elaboration.

Regarding the Teacher Knowledge Model used with preservice teachers (PST), we observe employment of various models developed in mathematics education (Figure 5), with predominance of MKT model (5/31; 16.13%).

While professional knowledge development has traditionally been associated with in-service teachers, our review of Table 3 reveals that 11 studies (35.5%) examine preservice teachers' (PST) performance on professional tasks resembling those encountered in actual teaching practice. Due to space limitations, we will not discuss these studies' findings here, as this topic warrants separate treatment.

Table 4 shows that the geometric content most frequently studied with In-Service Teachers (IST) relates to two-dimensional objects: triangles, squares, angles, and transformations. Regarding the Teacher Knowledge Model, the use of PCK predominates (2; 40 %). An equal number of studies do not specify the use of any model (2; 40 %), while the MKT models are used in fewer cases (1; 20 %).

Table 4
Studies with In-Service Teachers (IST)

#	Author	Knowledge model	Geometric Content	Educational Level
32	Leton et al. (2020)		Two-dimensional objects: triangles and squares	Elementary school
33	Kurt-Birel, et al. (2020)	PCK	Quadrilaterals, measurement of angles	Elementary school
34	Sunzuma, et al. (2020)		Two-dimensional objects	Middle school
35	Sunzuma & Maharaj (2019)	PCK	Geometry: basic concepts	Elementary school
36	Ng (2012)	MKT	Two-dimensional objects	Elementary and middle school

Note. Own elaboration.

It should be noted that studies involving only in-service teachers predominantly concentrate on creating proposals targeted at elementary and middle school education.

Table 5

Research Involving Pre-Service Teachers (PST) and In-Service Teachers (IST)

#	Author	Knowledge model	Geometric Content	Educational Level
37	Fernandes-Maia-Pereira, Kaiber (2022)	DMK	Flat geometry	Elementary school
38	Stupel & Ben-Chaim (2017)		Square, triangle, Pythagorean theorem	Elementary and middle school
39	Esendemir & Bindak (2019)	MKT	Triangle Area	Elementary and middle school
40	Gambini & Lénárt (2021)	MCK	Geometry compared between plane and sphere	Elementary and middle school

Note. Own elaboration.

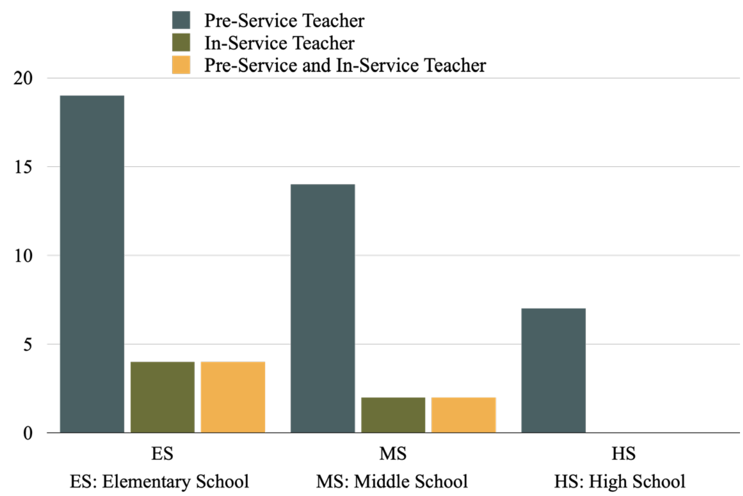
As shown in Table 5, the most frequent geometric content focuses on two-dimensional shapes, particularly squares and triangles. In terms of the Teacher Knowledge Model applied to both Pre-Service (PST) and In-Service Teachers (IST), no single model prevails.

An examination of the data in Tables 3, 4, and 5 shows that, from 40 analyzed articles, 77,5 % (n=31) involved Pre-Service Teachers (PST), compared to 12,2 % (n=5) exclusively addressing In-Service Teachers (IST) and 10 % (n=4) encompassing both groups. This distribution highlights a strong research bias toward PST in studies on Geometry Teacher Knowledge.

Regarding educational levels (elementary, high, and middle school), and their connection to PST or IST, Figure 6 illustrates this relationship. The data shows a predominance of the elementary school level across all participant categories (PST, IST, and both combined).

Figure 6

Distribution of Studies Across Elementary, Middle and High School Studies by Participant Type.



Note. Own elaboration.

Furthermore, the data reveal that as the educational level increases, the number of available studies declines. Notably, no research involving in-service teachers was identified at the middle school level.

Results Related to Objective O2: Findings on

In-ServiceTeachers

As previously mentioned, nine studies were identified: five involving exclusively in-service teachers (Table 4) and four examining both In-Service (IST) and Pre-Service teachers (PST) simultaneously (Table 5). The analysis carried out has helped identify key contributions and advancements to the study of teacher knowledge, which can be summarized as the following characteristics:

Validation of Instruments

Ng (2012) and Esendemir and Bindak (2019) reported validity and reliability results for an instrument measuring Mathematical Knowledge for Teaching Geometry (MKT-Geometry). The tool was translated from English into Indonesian and Turkish respectively for application in these two contexts. Both articles examined cultural, linguistic, and mathematical aspects emerging during the adapted instruments' development process. Psychometric analyses conducted on both instrument versions demonstrated high validity and reliability levels, supporting their use in the respective contexts.

Teacher's Professional Knowledge

The review has confirmed the need to improve both initial and ongoing teacher training processes in geometry, regarding both geometric content and its pedagogy, that is, the enhancement of teachers' professional knowledge in geometry. The results obtained by Sunzuma & Maharaj (2019), regarding the quality of initial teacher training, were inconclusive, as nearly half (52.5%) considered it adequate, while the other portion (47.5%) deemed it inadequate. Kurt-Birel et al. (2020) present findings from a training workshop and a subsequent geometry knowledge test administered to PS teachers. They observed weak geometric knowledge and even weaker PCK (Pedagogical Content Knowledge). Fernandes-Maia-Pereira & Kaiber (2022) presented the results of implementing a sequence of 24 activities designed to foster the acquisition and development of geometric knowledge among primary school students. These activities were developed with the participation of six Pre-Service Teachers (PST) and implemented with 48 In-Service Teachers (IST). The studies concluded that Pre-Service (PST) and In-Service Teachers (IST) require professional development incorporating theoretical-methodological tools like instructional process suitability analysis to enhance their mathematical-didactic knowledge and competencies.

Methodological Approaches

As proposals to develop teachers' professional knowledge, three out of nine studies report results when implementing innovative training methodologies. Specifically, Stupel & Ben-Chaim (2017) determined the effects of implementing problem-solving with multiple-solution tasks conducted with both PST and IST. According to the participants, the implemented methodology was considered valuable for developing thinking, reasoning, and creative skills. Therefore, the use of problems with multiple solutions is recommended in teacher training.

In a different approach, Sunzuma et al (2020) conducted a study on the usefulness of diagrams (graphical representations) in the teaching and learning processes of geometry. The opinions expressed by the teachers were predominantly positive, while also highlighting some negative aspects that may arise from the improper use of diagrams in the teaching and learning of geometry. In a related study, Gambini and Lénárt (2021) developed a methodological proposal using Lénárt spheres as a resource to stimulate discussion and reflection on the teaching practice of geometric objects, as well as to establish connections between PCK (Pedagogical Content Knowledge*)* and MCK (Mathematical Content Knowledge). They recommend the use of such resources to facilitate the transition between MCK and PCK.

Intervention Versus Diagnostic Assessment

A characteristic that creates duality among the analyzed studies refers to whether they included interventions aimed at developing teachers' professional knowledge or merely conducted a diagnosis of it. It was observed that five out of nine studies included: first, the use of training methodologies (Gambini & Lénárt, 2021; Stupel & Ben-Chaim, 2017; Sunzuma et al., 2020), second, the development of an instructional sequence and a reflection on its use (Fernandes-Maia-Pereira & Kaiber, 2022), and third, the design, implementation, and evaluation of a professional development workshop (Kurt-Birel et al., 2020). These studies implemented interventions aimed at developing teachers' professional knowledge. The remaining studies, particularly the one conducted by Leton et al. (2020), constitute exploratory research that solely diagnoses geometric knowledge among IST (Esendemir & Bindak 2019; Ng, 2012; Sunzuma et al., 2020).

As a common characteristic, the nine studies recognize the need to enhance initial teacher training in geometric content, teaching methods, resources representations, and multi-solution problem-solving. In other words, both content knowledge and pedagogical content knowledge must be strengthened. To achieve this, some of the studies recommend implementing professional development programs for in-service teachers or, alternatively, dedicating additional sessions during their initial training. Furthermore, these sessions should incorporate theoretical and methodological tools to help (prospective) teachers evaluate their growth in professional knowledge.

Conclusions

The implemented search process, detailed transparently to show how the 40 analyzed articles were identified using four information systems (WoS, Scopus, ERIC, and Google Scholar), has revealed trends and possible advancements achieved in research on geometry teacher's (professional) knowledge between 2012 and 2022. The observed trends show: first, a predominance of research conducted with pre-service teachers (77,5 %) over that conducted with in-service teachers (12,5 %). Second, a prevalence of studies on geometric content related to two-dimensional objects covered in elementary education (6-11 years). And, finally, the Mathematical Knowledge for Teaching (MKT) model's prevalence (15 %), with the use of at least eight different models being observed.

Regarding the predominance of studies conducted with PST, we believe that due to the inherent characteristics of teacher training programs in higher education (number of participants, mandatory nature, institutionalization, etc.), they offer a more conducive space for research development than the spaces provided by postgraduate and continuing education programs in general (Quintero et al., 2018). Various studies highlight the need to strengthen continuing education and its institutionalization, among other reasons, to provide greater opportunities for research in this field (Quintero et al., 2018). However, this issue would have to be addressed in another study.

Likewise, it was found that 11 (35,5 %) of the studies conducted with PST, reported on the performance of PST programs through the implementation of tasks designed to emulate professional teaching activities. This reveals how initial teacher education can foster the development of teachers' professional knowledge (Aparicio-Landa et al., 2021; Fernandes-Maia-Pereira & Kaiber, 2022; Gambini & Lénárt, 2021). This could represent a future trend in research on this knowledge type.

Regarding the diversity of teacher knowledge models identified, it is possible to distinguish at least two positions. One of them, proposed by Godino and collaborators (Godino, 2009; Godino et al., 2017; Pino-Fan & Godino, 2015), advocates for the articulation of existing models to create more comprehensive ones, where explanations about the complexity involved in the study and development of mathematics teachers' professional knowledge are complemented and made more precise. The other position refers to the coexistence of diverse models, suggesting that the theoretical dialogue between various frameworks can significantly enrich the scientific and academic discourse surrounding teacher knowledge (Scheiner et al., 2019).

On the other hand, regarding the trends and possible advances identified in research results on the development of geometry teachers' professional knowledge, there is a recognized need to design training programs – for both Pre-Service teachers (PST) and In-Service Teachers (IST) – that not only foster the development of disciplinary competencies but also equip educators to design and use more effective teaching resources. Additionally, such programs should address interaction methods that facilitate students' knowledge acquisition (Fernandes-Maia-Pereira & Keyber, 2022; Kurt-Birel et al., 2020; Sunzuma & Maharaj, 2019).

Some of the analyzed studies agree that the foundations of mathematical and geometric knowledge are incipient and linked to limited training, which has led to feelings of insecurity when approaching teaching practices (Ng, 2012;

Sunzuma & Maharaj, 2019). Fernandes-Maia-Pereira & Keyber (2022) emphasize the need for this training to incorporate specific analytical tools, grounded in theoretical–methodological frameworks, to foster the development and assessment of professional knowledge and competencies among mathematics teachers, both during initial training and in-service stages.

Among limitations encountered during this research, information accessibility stands out. The corpus was restricted to Open Access documents or those available through the university's institutional subscriptions. Additionally, the study's temporal boundaries and the reliance on title and abstract screening may have excluded relevant data. Future reviews could expand these results by improving access to information, expanding the information systems, extending the time frame, and including other sections such as the introduction and conclusions – or even the full document. Notably, the integration of Artificial Intelligence (AI) in systematic reviews offers a promising avenue for overcoming these constraints, potentially enabling more nuanced and granular data extraction in future research.

References

Adelabu F.M., & Alex J.K. (2022). Mathematical Knowledge for Teaching in Further Education and Training Phase: Evidence from Entry Level Student Teachers Baseline Assessments. *International Journal of Learning, Teaching and Educational Research*, *21*(8), 1-20. https://doi.org/10.26803/ijlter.21.8.1

Aparicio-Landa, E., Sosa-Moguel, L., & Cabanas-Sanchez, G. (2021). Reflective conversation and knowledge development in pre-service teachers: The case of mathematical generalization. *International Journal of Education in Mathematics, Science, and Technology,* *9*(1), 40-62. https://doi.org/10.46328/ijemst.977

Aslan-Tutak, F., & Adams, T.L. (2015). A study of geometry content knowledge of elementary preservice teachers. *International Electronic Journal of Elementary Education*, *7*(3), 301-318. https://www.iejee.com/index.php/IEJEE/article/view/82

Ball, D.L. (2000). Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. *Journal of Teacher Education, 51*(3), 241-247. https://doi.org/10.1177/0022487100051003013

Ball, D.L., Lubienski, S.T., & Mewborn, D.S. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4a ed.) (pp. 433-456). Macmillan.

Bonyah, E., & Larbi, E. (2021). Assessing van Hiele's geometric thinking levels among elementary pre-service mathematics teachers. *African Educational Research Journal*, *9*(4), 844-851. https://doi.org/10.30918/AERJ.94.21.119

Carrillo, J., Climent, N., Contreras, L.C., & Muñoz-Catalán, M.D.C. (2013). Determining specialised knowledge for mathematics teaching. In B. Ubuz, Ç. Haser, & M.A. Mariotti (Eds.), *Proceedings of the CERME 8* (pp. 2985-2994). ERME.

Castro, W.F., Durango-Urrego, J.H., & Pino-Fan, L.R. (2021). Preservice Teachers' Argumentation and Some Relationships to Didactic-Mathematical Knowledge Features. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(9), 1-20. https://doi.org/10.29333/ejmste/11139

Clemente, F. & Llinares, S. (2015). Formas del discurso y razonamiento configural de estudiantes para maestros en la resolución de problemas de geometría. *Enseñanza de las Ciencias*, *33*(1), 9-27. https://raco.cat/index.php/Ensenanza/article/view/288569

Climent, N. (2002). *El desarrollo profesional del maestro de primaria respecto de la enseñanza de la matemática: un estudio de caso*. [Tesis de doctorado, Universidad de Huelva] Arias Montano Repositorio Institucional de la Universidad de Huelva. http://hdl.handle.net/10272/2742

Creswell, J. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

Dündar, S., & Gündüz, N. (2017). Justification for the Subject of Congruence and Similarity in the Context of Daily Life and Conceptual Knowledge. *Journal on Mathematics Education,* *8*(1), 35-54. http://dx.doi.org/10.22342/jme.8.1.3256.35-54

Ekawati, R.M., Rosyidi, A.H., Prawoto, B.P., Prahmana, R.C.I., & Lin, F.L. (2022). Developing a Constructive Conceptual Framework of a Pre-Service Mathematics Teachers' Content Knowledge Instrument on Space and Shape. *Mathematics 2022, 10*(1), 1-15. https://doi.org/10.3390/math10010137

Eli, J.A., Mohr-Schroeder, M.J., & Lee, C.W. (2013). Mathematical Connections and Their Relationship to Mathematics Knowledge for Teaching Geometry. *School Science and Mathematics, 113*(3), 120-134. https://doi.org/10.1111/ssm.12009

Erkek, Ö., & Isiksal-Bostan, M. (2019). A Different Look at the Reasoning Process of Prospective Middle School Mathematics Teachers: Global Argumentation Structures. *Education and Science, 44*(199), 1-27. http://dx.doi.org/10.15390/EB.2019.7867

Esendemir, O., & Bindak, R. (2019). Adaptation of the test developed to measure Mathematical knowledge of teaching Geometry in Turkey. *International Journal of Educational Methodology, 5*(4), 547-565. https://doi.org/10.12973/ijem.5.4.547

Fernandes-Maia-Pereira, S., & Kaiber, C.T. (2022). Didactic-Mathematical Knowledge and Teacher Education: An Investigation with Pre-Service and In-Service Mathematics Teachers. *Acta Scientiae, 24*(6), 606-633. https://doi.org/10.17648/acta.scientiae.6243

Florio, E. (2022). The Parabola: Section of a Cone or Locus of Points of a Plane? Tips for Teaching of Geometry from Some Writings by Mydorge and Wallis. *Mathematics 10*(6), 1-18. https://doi.org/10.3390/math10060974

Gambini, A., & Lénárt, I. (2021). Basic Geometric Concepts in the Thinking of In-Service and Pre-Service Mathematics Teachers. *Education Sciences*, *11*(7), 1-12. https://doi.org/10.3390/educsci11070350

Godino, J.D. (2009). Categorías de análisis de los conocimientos del profesor de matemáticas. *Unión, Revista Iberoamericana de Educación Matemática, 20*, 13-31. http://hdl.handle.net/20.500.12799/3098

Godino, J.D., Giacomone, B., Batanero, C., & Font, V. (2017). Enfoque ontosemiótico de los conocimientos y competencias del profesor de matemáticas. *Bolema: Boletim de Educação Matemática*, *31*(57), 90-113. https://doi.org/10.1590/1980-4415v31n57a05

Grossman, P.L. (1990). *The making of a teacher: teacher knowledge and teacher education*. Teachers College Press Columbia University.

Gumiero, B.S., & Pazuch, V. (2021). Teachers Knowledge Mobilized in Geometry Lessons and Contingency Situations. *International Electronic Journal of Mathematics Education, 16*(1), 2-14. https://doi.org/10.29333/iejme/9371

Hill, H.C., Ball, D.L., & Schilling, S.G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education, 39*(4), 372-400. https://doi.org/10.5951/jresematheduc.39.4.0372

Hourigan, M., & Leavy, A. (2017). Preservice Primary Teachers' Geometric Thinking: Is Pre-Tertiary Mathematics Education Building Sufficiently Strong Foundations?. *The Teacher Educator*, *52*(4), 346-364. https://doi.org/10.1080/08878730.2017.1349226

Huang, C., Yang, C., Wang, S., Wu, W., Su, J., & Liang, C. (2020) Evolution of topics in education research: a systematic review using bibliometric analysis. *Educational Review, 72*(3), 281-297. https://doi.org/10.1080/00131911.2019.1566212

İlhan, A., & Aslaner, R. (2021). Analysis of the Correlations Between Visual Mathematics Literacy Perceptions, Reasoning Skills on Geometric Shapes and Geometry Performances of Pre-Service Mathematics Teachers. *Participatory Educational Research, 8*(1), 90-108. https://doi.org/10.17275/per.21.5.8.1

Karagöz-Akar, G. (2015). Prospective Secondary Mathematics Teachers' Perspectives and Mathematical Knowledge for Teaching. *EURASIA Journal of Mathematics, Science & Technology Education, 12*(1), 3-24. https://doi.org/10.12973/eurasia.2015.1378a

Kurt-Birel, G., Deniz, S., & Önel, F. (2020). Analysis of Primary School Teachers' Knowledge of Geometry. *International Electronic Journal of Elementary Education, 12*(4), 303-309. https://doi.org/10.26822/iejee.2020459459

Leton, S.I., Djong, K.D., Uskono, I.V., Dosinaeng, W.B.N., & Lakapu, M. (2020). Profile of elementary school teacher in concept understanding of geometry. *Infinity, 9*(2), 133-146. https://doi.org/10.22460/infinity.v9i2.p133-146

Liñán-García, M., Muñoz-Catalán, M., Contreras, L., & Barrera-Castarnado, V. (2021). Specialised Knowledge for Teaching Geometry in a Primary Education Class: Analysis from the Knowledge Mobilized by a Teacher and the Knowledge Evoked in the Researcher- *Mathematics 9*(21),1-18. https://doi.org/10.3390/math9212805

Martín-Martín, A., Orduna-Malea, E., Thelwall, M., & López-Cózar, E.D. (2018). Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *Journal of informetrics, 12*(4), 1160-1177. https://doi.org/10.1016/j.joi.2018.09.002

Ministerio de Educación Nacional (MEN). (2006). Estándares básicos de competencias matemáticas. En MEN (Ed.)*, Estándares básicos de competencias en Lenguaje, Matemáticas, Ciencias y Ciudadanas* (pp. 46-95). MEN.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D.G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ*, *339*. https://doi.org/10.1136/bmj.b2535

Montes, M., Climent, N., & Contreras, L.C. (2022). Construyendo conocimiento especializado en geometría: un experimento de enseñanza en formación inicial de maestros. *Aula Abierta, 51*(1), 27-36. https://doi.org/10.17811/rifie.51.1.2022.27-36

Morales-López, Y. (2019). Knowledge evidenced by prospective mathematics teachers when performing a task involving geometry, teaching and the use of technology. *Acta Scientiae 21*(2), 75-92. https://doi.org/10.17648/acta.scientiae.v21iss2id5081

Nason, R., Chalmers, C., & Yeh, A. (2012). Facilitating growth in prospective teachers' knowledge: teaching geometry in primary schools. *Journal of Mathematics Teacher Education, 15*, 227-249. https://doi.org/10.1007/s10857-012-9209-0

Newman, M., & Gough, D. (2020). Systematic reviews in educational research: Methodology, perspectives and application. In O. Zawacki-Richter, M. Kerres, S. Bedenlier, M. Bond, & K. Buntins (Eds.), *Systematic reviews in educational research: Methodology, perspectives and application* (pp. 3-22). Springer.

Ng, D. (2012). Using the MKT measures to reveal Indonesian teachers' mathematical knowledge: challenges and potentials. *ZDM Mathematics Education 44*, 401-413. https://doi.org/10.1007/s11858-011-0375-9

Niyukuri, F., Nzotungicimpaye, J., & Ntahomvukiye, C. (2020). Pre-Service Teachers' Secondary School Experiences in Learning Geometry and their Confidence to Teach It. *EURASIA Journal of Mathematics, Science and Technology Education, 16*(8), 1-12. https://doi.org/10.29333/ejmste/8334

Özdemir, F. (2022). Examining Pre-Service Teachers' Views on Reasoning, Developing Reasoning and Importance of Reasoning Skills in Geometry. *Acta Didactica Napocensia, 15*(2), 1-12. https://doi.org/10.24193/adn.15.2.1+H24

Özçakir, B. (2019). Prospective Mathematics Teachers' Technology Usages: A Case for Dynamic Geometry Software. *Acta Didactica Napocensia, 12*(1), 1-15. https://doi.org/10.24193/adn.12.1.1

Paré, G., Trudel, M.C., Jaana, M., & Kitsiou, S. (2015). Synthesizing information systems knowledge: A typology of literature reviews. *Information & management, 52*(2), 183- 199. https://doi.org/10.1016/j.im.2014.08.008

Pino-Fan, L.R. & Godino, J.D. (2015). Perspectiva ampliada del conocimiento didáctico-matemático del profesor. *Paradigma, 36*(1), 87-109.

Ponte, J.P., & Chapman, O. (2006). Mathematics teachers' knowledge and practices. En A. Gutiérrez & P. Boero (Eds), *Handbook of Research on the Psychology of Mathematics Education: Past, present and future*, (pp. 461-494). Sense Publishers. https://doi.org/10.1163/9789087901127_017

Quintero T., Jamer J., Jaña M., Esteban, C. & Rivera, P.J. (2018). Tendencias de investigación en formación permanente de profesores: estado del arte e interpretación de actores clave. *Actualidades Investigativas en Educación, 18*(2), 353-382. https://dx.doi.org/10.15517/aie.v18i2.33174

Robbins, J.B. (2001). ERIC: Mission, structure, and resources. *Government Information Quarterly, 18*(1), 5-17. https://doi.org/10.1016/S0740-624X(00)00062-9

Rowland, T., Huckstep, P., & Thwaites, A. (2005). Elementary Teachers' Mathematics Subject Knowledge: the Knowledge Quartet and the Case of Naomi. *Journal of Mathematics Teacher Education, 8*, 255-281. https://doi.org/10.1007/s10857-005-0853-5

Saralar-Aras, İ., & Birgili, B. (2022). An assessment of pre-service mathematics teachers' techno-pedagogical content knowledge regarding geometry. *International Journal of Psychology and Educational Studies, 9*(4), 1307-1327. https://dx.doi.org/10.52380/ijpes.2022.9.4.920

Segal, R., Oxman, V., & Stupel, M. (2021). Using Dynamic Geometry Software to Enhance Specialized Content Knowledge: Pre-Service Mathematics Teachers' Perceptions. *International Electronic Journal of Mathematics Education*, *16*(3), 1-8. https://doi.org/10.29333/iejme/11065

Scheiner, T., Montes, M.A., Godino, J.D. Carrillo, J. & Pino-Fan, L.R. (2019). What Makes Mathematics Teacher Knowledge Specialized? Offering Alternative Views. *International Journal of Science and Mathematics Education, 17*, 153-172. https://doi.org/10.1007/s10763-017-9859-6

Schoenfeld, A.H., & Kilpatrick, J. (2008). Toward a theory of proficiency in teaching mathematics. In T. Wood, & D. Tirosh, (ed.), *International handbook of mathematics teacher education*, (pp. 321-354). Sense Publishers.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14. https://doi.org/10.3102/0013189X015002004

Smith, C.R., Julie, C., & Gierdien, F. (2020). The integration of semiotic resources and modalities in the teaching of geometry in a Grade 9 class in a South African high school: The four cases of congruency. *South African Journal of Education, 40*(2),1-12. https://doi.org/10.15700/saje.v40n2a1682

Stupel, M., & Ben-Chaim, D. (2017). Using multiple solutions to mathematical problems to develop pedagogical and mathematical thinking: A case study in a teacher education program. *Investigations in Mathematics Learning, 9*(2), 86-108. https://doi.org/10.1080/19477503.2017.1283179

Sunzuma, G., & Maharaj, A. (2019). In-service teachers' geometry content knowledge: Implications for how geometry is taught in teacher training institutions. *International Electronic Journal of Mathematics Education, 14*(3), 633-646.

Sunzuma, G., Chando, C., Gwizangwe, I., Zezekwa, N., & Zinyeka, G. (2020). In-Service Zimbabwean Teachers' Views on the Utility Value of Diagrams in the Teaching and Learning of Geometry. *LUMAT: International Journal on Math, Science and Technology Education*, *8*(1), 1-18. https://journals.helsinki.fi/lumat/article/view/1316/1334

Tefera, A., Atnafu, M., & Michael, K. (2021). The Relevance of Current Ethiopian Primary School Teacher Education Program for Pre-Service Mathematics Teacher's Knowledge and Teacher Educator's Awareness about Mathematics Knowledge for Teaching. *EURASIA Journal of Mathematics, Science and Technology Education,17*(5), 1-17. https://eric.ed.gov/?id=EJ1296862

Tertemiz, N. (2012). The effects of project- and activity-supported practices on mathematics education achievement and student views. *Eurasian Journal of Educational Research*, *46*, 159-178.

Ubah, I. (2021). Pre-service mathematics teachers' semiotic transformation of similar triangles: Euclidean geometry. *International Journal of Mathematical Education in Science and Technology, 53*(8), 2004-2025. https://doi.org/10.1080/0020739X.2020.1857858

Vieira, A.F.M., & de Costa-Trindade-Cyrino, M.C. (2022). Geometric Thinking: Reflections Manifested by Preservice Mathematics Teachers in van Hiele Model Studies, *Acta Scientiae, 24*(8), 286-314. https://doi.org/10.17648/acta.scientiae.7164

Vodušek, H.B., & Lipovec, A. (2014). The square as a figural concept, *Waikato Journal of Education*, *28*(48), 430-448. https://doi.org/10.1590/1980-4415v28n48a21

Yi, M., Wang, J., Flores, R., & Lee, J. (2022). Measuring pre-service elementary teachers' geometry knowledge for teaching 2-dimensional shapes. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(8), 1-15. https://eric.ed.gov/?id=EJ1356755

Zambak, V., & Tyminski, A. (2020). Examining mathematical technological knowledge of pre-service middle grades teachers with Geometer's Sketchpad in a geometry course. *International Journal of Mathematical Education in Science and Technology, 51*(2), 183-207. https://doi.org/10.1080/0020739X.2019.1650302

Zhu, J., & Liu, W. (2020). A tale of two databases: the use of Web of Science and Scopus in academic papers. *Scientometrics, 123*, 321-335. https://doi.org/10.1007/s11192-020-03387-8