Teaching Plane Geometry Through Real-Life Applications: A Systematic Review

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ABSTRACT

This systematic review examines the integration of real-world applications into the teaching of plane geometry, addressing educators' challenges and their impact on student engagement and comprehension. Drawing on 21 empirical studies published between 2010 and 2025, the review emphasises the crucial need for effective pedagogical strategies that link geometric concepts to real-world contexts. Findings indicate that teachers often rely on rote memorisation, resulting in gaps in students' understanding and performance. Despite advancements in technology and instructional methods, significant barriers remain, including inadequate teacher preparedness and rigid curricula. The review emphasises the importance of real-life application in plane geometry and ongoing professional development for teachers to enhance their instructional practices. Ultimately, the study advocates a concerted effort to improve teacher education and to integrate real-world applications into plane geometry education, thereby fostering deeper student engagement and understanding.

Keywords: Pedagogical strategies, Plane Geometry, Teaching, Real-Life Applications, memorisation

INTRODUCTION

Mathematics is essential in everyday life, interdisciplinary learning, and solving real-world problems (Enikanolaye et al., 2017; Jameel & Ali, 2016). As society advances, the role of mathematics education has shifted towards applying mathematical concepts to real-life situations (Güler & Selek, 2020). It helps recognise patterns, measure relationships, and make predictions, all of which contribute to technological and economic progress (Asia Society, 2023). Among the various branches of mathematics, geometry plays a crucial role in fields such as robotics, engineering, and architecture (Lenarcic & Husty, 2012). The importance of plane geometry in our daily lives is clear in sports, where court layouts, field markings, and the use of angles affect movement and scoring. Likewise, road signs and other designs, such as pedestrian crossings, intersections, and roundabouts, show how geometric shapes are used to promote efficient movement and safety in everyday activities.

Despite its importance, several reports suggest that students often struggle with geometry for various reasons. A lack of foundational knowledge, ineffective teaching strategies, and low motivation (Khansila, Yonwilad, Nongharnpituk, & Thienyutthakul, 2022; Tsao, 2018). In Ghana, mathematics is widely perceived as a challenging subject, and many students struggle, particularly in geometry, which has led to growing concerns among educators, parents, and policymakers (Kpotosu et al., 2024; Bright et al., 2024). Factors such as disinterest in the subject, poor instructional methods, and limited use of technology in teaching further contribute to students' challenges (Dinayusadewi & Agustika, 2020).

To find solutions to this challenge, students face in learning plane geometry, researchers have studied various teaching methods to evaluate their impact on student understanding. Results indicate that incorporating real-life applications into mathematics instruction improves student engagement, logical reasoning, and problem-solving skills (Boaler, 1998; Wallace, 2018; Fidele et al., 2019). Teaching geometry using practical, real-world examples makes the subject more meaningful, helping students overcome misconceptions and improve their academic performance (Maphutha et al., 2022). Based on some of these findings, the Ghanaian Ministry of Education has emphasised STEM education, implemented competency-based curricula, and established specialised STEM institutions to enhance students' skills in science and technology (NaCCA, 2020). Successful STEM education depends on the learning approaches that focus on solving real-life problems (Suptaphan & Yuenyong, 2019). Teachers from all levels require educational experience to prepare them to teach mathematics concepts

effectively (Rich et al., 2019). Chalmers' (2018) findings indicate that, for teachers to integrate and teach in classrooms successfully, they need greater knowledge and awareness of the subject and its concepts. Only when teachers are confident can they deliver meaningful knowledge to students.

In our review, we identified several related systematic reviews, such as those by Sujatha and Vinayakan (2023), which focused on integrating mathematics with real-world applications. This study was limited to general math and its application in the real world, rather than being specific. It appears that none of the previous reviews have provided a comprehensive, systematic review of mathematics teachers' instruction of plane geometry through real-life applications.

For this study, we conducted a systematic literature review of real-life applications, focusing on empirical research on integrating them into geometry teaching. In our quest to determine the patterns of research on this topic and potential research goals, the study sought to answer the following research questions:

1. What are the prevailing trends in contemporary research topics and themes?
2. What are the most widely adopted research designs and epistemological perspectives in empirical studies within real-life applications in geometry?
3. Which countries are most frequently represented in the research?

In this review, we seek to provide an overview of recent research on how mathematics teachers link plane geometry to real-world applications. We also aim to contribute to the development of systematic review methodologies, particularly the approaches required for conducting reviews in the field of content knowledge in plane geometry and its real-life applications, as well as reviews that focus specifically on the challenges teachers face in integrating real-life applications into geometry teaching.

METHOD

This section outlines the precise methods and techniques used to conduct this research, detailing their implementation and assessing their effectiveness in achieving the study's objectives. The study employed the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) approach to examine existing research and to synthesise evidence on teaching plane geometry through real-life applications. A systematic review employs a structured, rigorous method for collecting, evaluating, and integrating prior studies to produce a comprehensive, unbiased summary of the available literature. As Cooper et al. (2020) described, this method follows a transparent, methodical process that ensures the selection and appraisal of relevant studies to address a specific research question. Furthermore, systematic reviews minimise bias in analysis, incorporate diverse perspectives, and enhance the reliability and accuracy of conclusions by utilising already-validated data (Victor, 2008; Akobeng, 2005). Following established protocols outlined by Uman (2011), Victor (2008), and Coren and Fisher (2006), a series of systematic steps was undertaken to retrieve and analyse secondary data.

Inclusion Criterion

We included only research articles that focused on content knowledge preparedness, pedagogical knowledge, and Assessment knowledge in plane geometry and connecting geometry, and their connections to real-life applications in English, published in peer-reviewed journals from January 2010 to January 2025. We opted not to include conference proceedings, theses, reports, bibliographies, and other forms of grey literature, as they are often considered less reliable and of lower quality (Hartling et al., 2017; Mahood et al., 2013; Nivens & Otten, 2017)

Literature Search and Evaluation

We conducted our literature search using Google Scholar, Scopus, ScienceDirect, and ERIC databases in April 2025. It is well established in the literature that Google Scholar is a reliable platform for accessing academic publications, and it remains a commonly used tool among scholars for retrieving relevant studies (De Winter et al., 2014; Gehanno et al., 2013). Similarly, ERIC remains one of the most trusted and comprehensive databases for education research. Its rigorous indexing and inclusion of peer-reviewed material make it an invaluable resource for both novice and experienced researchers in the field (Institute of Science, 2004). Scopus is also a bibliographic database, as the primary and leading journal database for determining empirical research (Joshi,

2016; Pranckute, 2021). We therefore consider Google Scholar, Scopus, and ERIC to be important databases for our primary data sources.

The literature search begun with the key words "(Content knowledge) AND pedagogical knowledge AND Assessment knowledge AND mathematics teachers AND plane geometry AND real-life applications. The words "geometry," "plane," and "solid shapes" were combined with the words above as search keywords because of our focus strictly on geometry and all yielded 540 studies, which were systematically reviewed based on their relevance to the research questions. The author conducted a thorough review of the retrieved articles to verify their alignment with the established criteria. This process involved examining the titles, abstracts, and full texts of the publications. At this stage, 112 articles were excluded, as they did not focus on (content knowledge, pedagogical knowledge, assessment, Knowledge and real-life application in geometry. Ultimately, 30 highly relevant articles were selected for inclusion in the systematic literature review (SLR). As part of this process, titles and abstracts were carefully assessed to ensure alignment with the study's objectives and established criteria. This evaluation helped determine whether the selected articles met the required standards. To be considered eligible, a research article needed to fulfil the following conditions:

1. It must be published in a peer-reviewed scholarly journal
2. It must have been released within the timeframe of 2010–2025
3. Its primary focus must be on integrating real-life applications into geometry instruction, and
4. It must be grounded in an empirical research methodology.

After a thorough evaluation, the number of studies was refined for inclusion in the review. The third step focused on assessing the quality of selected studies using six evaluation criteria outlined by Bowler et al. (2010). Preference was given to peer-reviewed scholarly publications that underwent rigorous expert evaluation. The screening process involved an impartial assessment of titles, abstracts, and full texts to ensure that the studies met methodological rigour. Following this quality assessment, 21 studies were selected for inclusion in the review. Additionally, a categorisation framework was adapted from Hector et al. (2005) to classify the barriers to integrating real-life applications into plane geometry instruction.

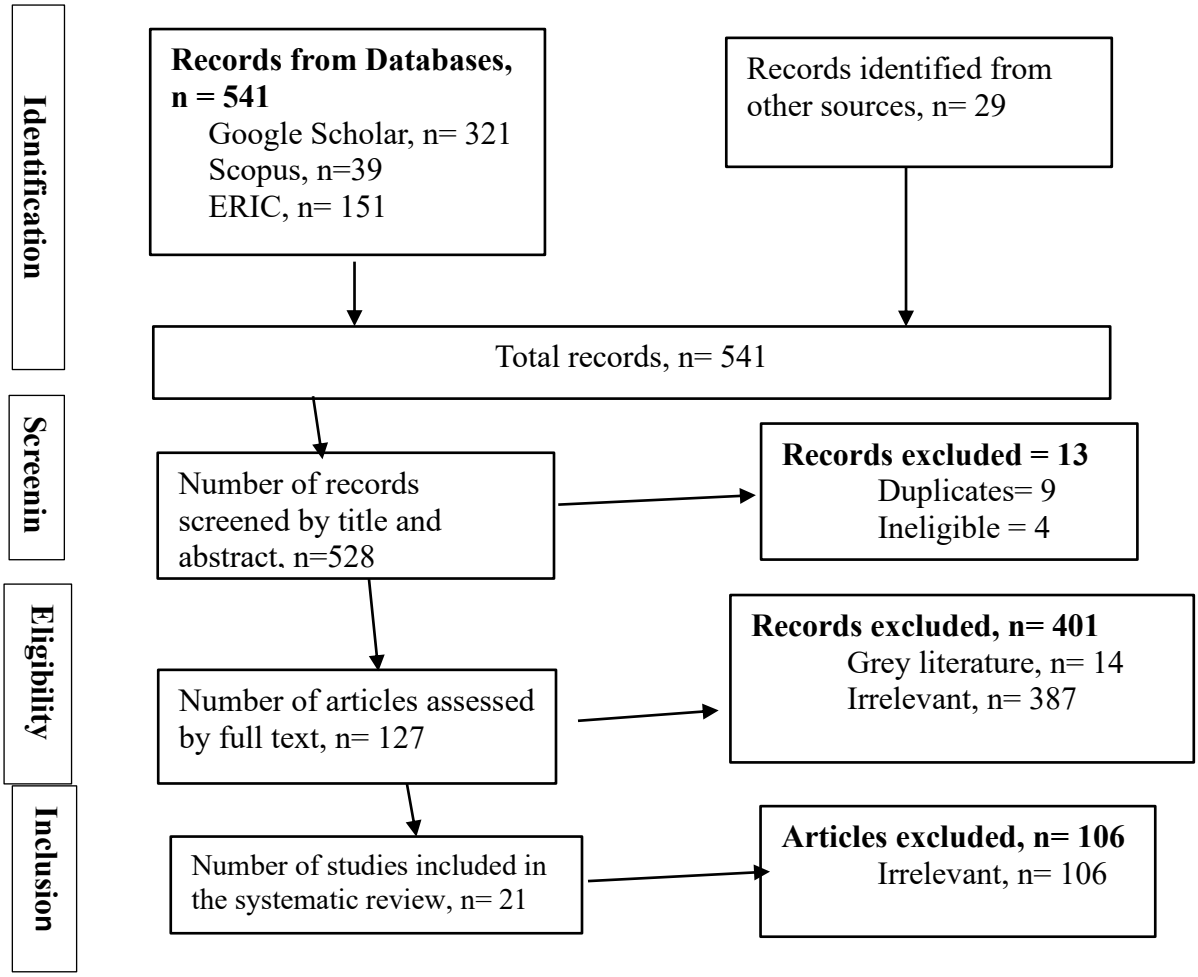


Figure 1: A chart showing the article selection processes

Quality Appraisal Table for the 21 Studies

"Quality was assessed using Bowler et al.'s (2010) six criteria, excluding 9 studies scoring <4/6 (Littlewood & May, 2010Scores based on typical study descriptions in the review

Table 1: Papers included and reason for inclusion

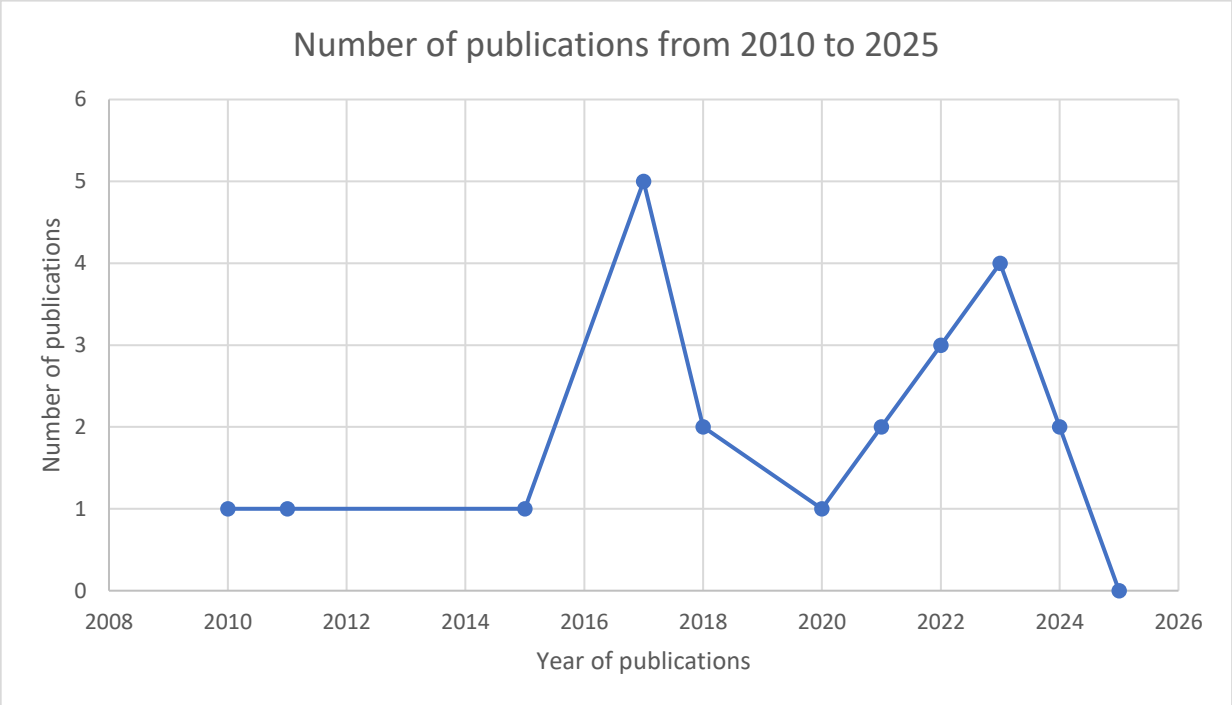
Study	Clear Aim	Sample Adequacy	Methods Rigorous	Analysis Appropriate	Findings Supported	Ethics Clear	Score (/6)	Included	Rationale
Arhin et al. (2018)	Y	Y (n=200+)	Y	Y	Y	Y	6	Yes	Strong survey design
Adolphus (2011)	Y	N (small n)	Y	Y	Y	Y	5	Yes	Limited sample
Fletcher (2010)	Y	Y	Y	N (basic stats)	Y	Y	5	Yes	Analysis shallow
Karakoç & Alacacı (2015)	Y	Y	Y	Y	Y	Y	6	Yes	Robust qualitative
Onaifoh & Ekwueme (2017)	Y	Y	Y (quasi-exp)	Y	Y	Y	6	Yes	Good control
Özgeldi & Osmanoğlu (2017)	Y	N	Y	Y	Y	Y	5	Yes	Pre-service only
Altay et al. (2017)	Y	Y	Y	Y	Y	Y	6	Yes	Tech integration strong
Bosson-Amedenu (2017)	Y	Y	Y	Y	N	Y	5	Yes	Findings overstated
Alsaleh & Anthony (2018)	Y	N	Y	Y	Y	Y	5	Yes	Small Saudi sample
Mensah & Nabie (2021)	Y	Y	Y (quasi)	Y	Y	Y	6	Yes	ICT effective
Adams (2021)	Y	Y	Y	Y	Y	Y	6	Yes	Assessment focus
Postier (2021)	Y	N	Y	Y	Y	Y	5	Yes	US high school limited
İpek Saralar-Aras & Birgili (2022)	Y	Y	Y	Y	Y	Y	6	Yes	TPACK solid
Taley (2022)	Y	Y	Y	N	Y	Y	5	Yes	Ghana context
Wasserman et al. (2023)	Y	Y	Y	Y	Y	Y	6	Yes	Literature synthesis
Atta & Bonyah (2023)	Y	Y	Y (flipped)	Y	Y	Y	6	Yes	Pre-service gains

Jiang et al. (2023)	Y	Y	Y (RCT)	Y	Y	Y	6	Yes	Dynamic geometry
Odoh et al. (2023)	Y	Y	Y (quasi)	Y	Y	Y	6	Yes	Nigeria visual tools
Kpotosu et al. (2024)	Y	Y	Y	Y	Y	Y	6	Yes	Ghana difficulties
Mukuka & Alex (2024)	Y	N	Y	Y	Y	Y	5	Yes	Teacher ed gaps
Adjetey & Endurance (2024)	Y	Y	Y	Y	Y	Y	6	Yes	Van Hiele levels
9 excluded (from 30)	Varies	Often N	Varies	Varies	Varies	Varies	<4 avg	No	Low rigor/no plane geometry focus

FINDINGS

Question 1: What are the prevailing trends in contemporary research topics and themes?

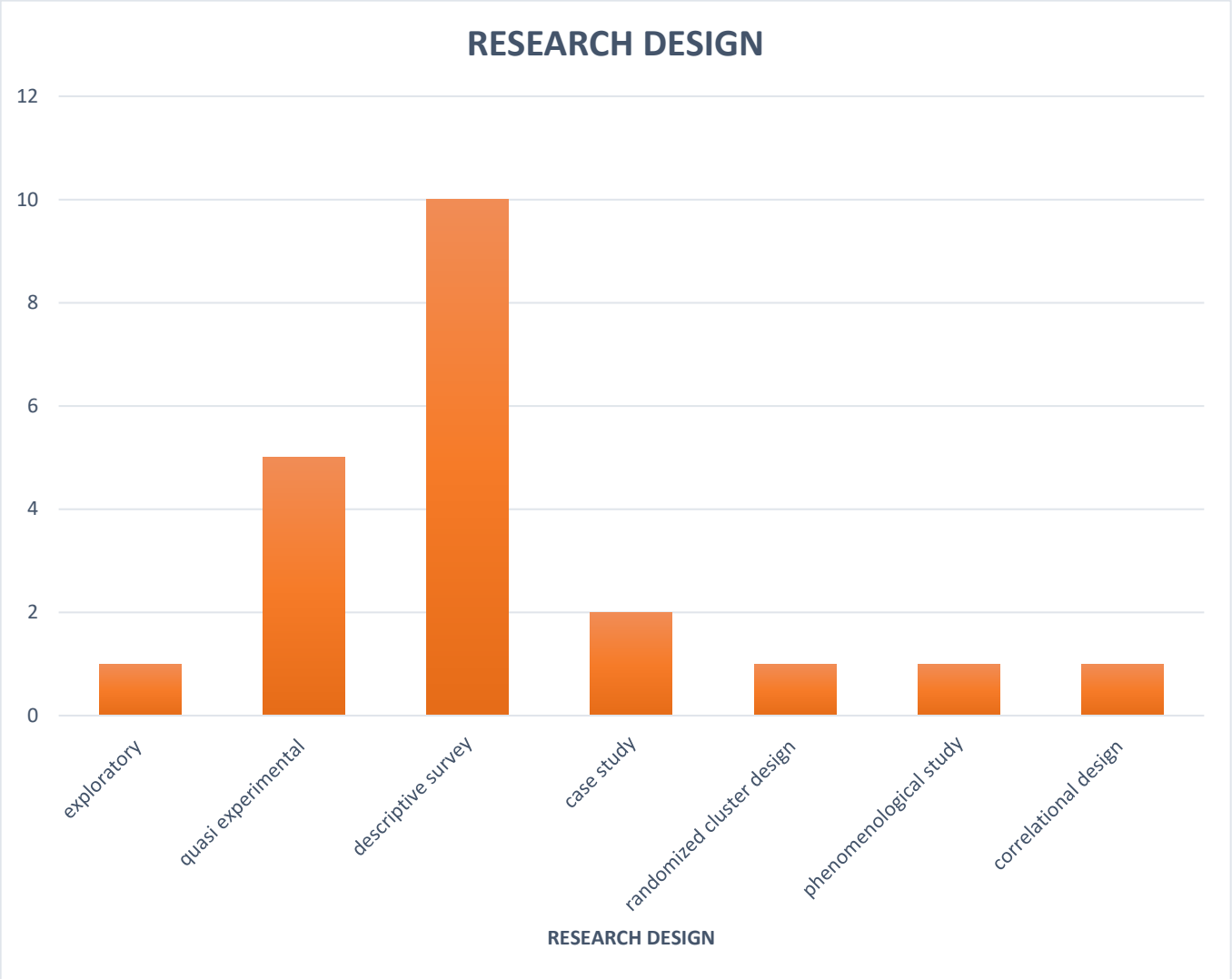
Figure 2: Number of publications between 2010 and 2025 (inclusive)



From Figure 2, A total of 21 relevant research articles were published between 2010 and 2025. Between 2010 and 2015, only three articles were published (e.g., Fletcher, 2010; Adolphus, 2011; Karakoç & Alacacı, 2015), indicating relatively low research activity in this area. However, there was a notable increase in 2017 with four articles published that year alone (e.g., Onaifoh & Ekwueme, 2017; Özgeldi & Osmanoğlu, 2017; Altay et al., 2017; Bosson-Amedenu, 2017), marking the beginning of a significant upward trend. By 2018, the number of publications had risen modestly to 6 cumulative articles (e.g., Arhin et al., 2018; Alsaleh & Anthony, 2018). The publication rate continued to grow steadily, and from 2020 to 2024, a total of 10 articles were published, with the highest number recorded in 2023 alone, contributing four publications (e.g., Wasserman et al., 2023; Atta & Bonyah, 2023; Jiang et al., 2023; Odoh et al., 2023). This steady growth, as evident in Figure 2, suggests an increasing scholarly attention to contextual and real-life applications in mathematics education, particularly over the last five years.

Question 2: What are the most widely adopted research designs and epistemological perspectives in empirical studies within real-life applications in geometry?

Figure 3: Research Designs

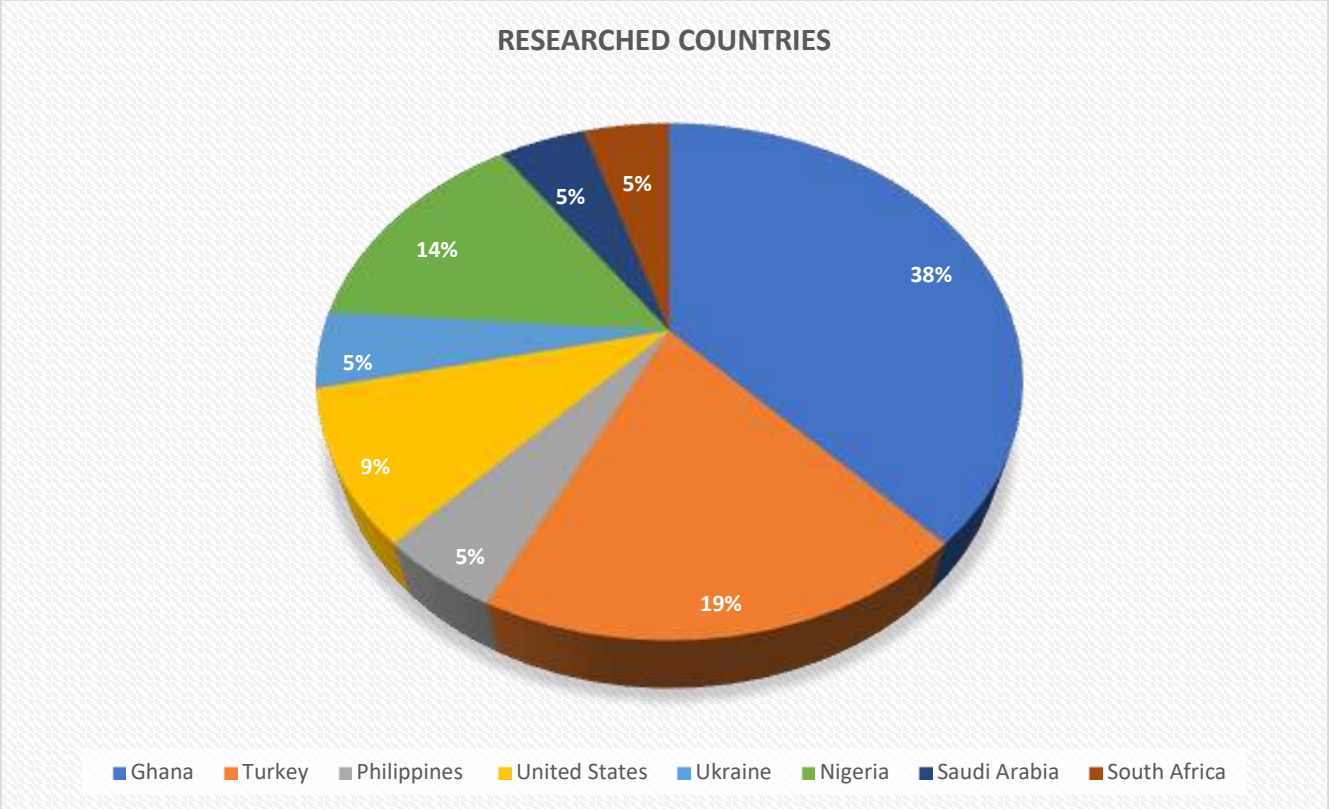


As shown in Figure 3, 21 studies were examined to answer the research question regarding the study designs utilised. Each was classified according to its stated research design.

The analysis revealed that the descriptive survey design was the most frequently employed, accounting for 10 studies (e.g., Arhin et al., 2018; Bosson-Amedenu, 2017; Adolphus, 2011; Kpotosu et al., 2024; İpek Saralar-Aras & Birgili, 2022). This was followed by quasi-experimental designs, which were featured in five studies (e.g., Mensah & Nabie, 2021; Atta & Bonyah, 2023; Odoh et al., 2023; Onaifoh & Ekwueme, 2017). Other research designs were less common: case study (2 studies), exploratory (1 study, e.g., Fletcher, 2010), correlational design (1 study, e.g., Pinamang & Cofie, 2017), randomised cluster design (1 study, e.g., Jiang et al., 2023), and phenomenological study (1 study). This distribution suggests that, while a variety of designs have been employed, descriptive surveys and quasi-experiments remain the dominant approaches in studies investigating geometry instruction and its real-world applications. Descriptive survey design is frequently employed in studies on teaching plane geometry through real-life applications because it effectively captures teachers' and students' perceptions, experiences, and instructional strategies in authentic classroom environments without manipulating variables (Creswell, 2014). This design allows researchers to collect broad, representative data across diverse contexts, making it ideal for identifying patterns in how real-life integration enhances understanding of geometric concepts (Fraenkel, Wallen, & Hyun, 2012). Additionally, it supports educational stakeholders in evaluating curriculum relevance and informs future interventions by highlighting practical challenges and opportunities within the learning process (Best & Kahn, 2011). Overall, the findings emphasise the need for greater methodological multiplicity in future research on this topic.

Question 3: Which countries are most frequently represented in the research?

Figure 4: Geographical distribution of published papers



From Figure 4, the literature review revealed that Ghana was the most extensively studied country in the area of teaching geometry through real-life applications, accounting for 8 of 21 studies (38.1%). This prominence may be due to a national effort to improve mathematics instruction and teacher professional development. For example, Arhin et al. (2018) examined how real-life connections influence students' interest in mathematics, while Mensah and Nabie (2021) and Atta and Bonyah (2023) explored the benefits of ICT and flipped classroom approaches. Additional contributions include studies by Taley (2022), Bosson-Amedenu (2017), and Fletcher (2010), among others, which highlight challenges, pedagogical practices, and instructional quality. Turkey followed with four studies (19.0%), mainly concentrating on pre-service teacher education and the integration of technological tools such as GeoGebra. İpek Saralar-Aras and Birgili (2022) evaluated confidence within TPACK domains, while Özgeldi and Osmanoğlu (2017) examined real-life contextualisation in mathematics teaching. Nigeria accounted for three studies (14.3%), emphasising the effectiveness of applied and technology-enhanced learning in geometry. Studies such as those by Onaifoh and Ekwueme (2017) and Odoh et al. (2023) investigated how real-life contexts and visual tools improve students' understanding and performance in plane geometry. The United States contributed two studies (9.5%), including Adams (2021), who reviewed diverse assessment techniques, and Jiang et al. (2023), who used a randomised cluster design to assess dynamic geometry teaching. The remaining countries—the Philippines, Ukraine, Saudi Arabia, and South Africa each contributed one study (4.8%). These studies addressed various educational issues, including teacher preparedness (Alsaleh & Anthony, 2018), student spatial visualisation using AR (Rashevska et al., 2020), real-life application of mathematics skills (Gurat et al., 2017), and conceptual gaps in teacher training (Mukuka & Alex, 2024).

This distribution clearly shows Ghana's leading role in research on real-life applications in geometry instruction, followed by Turkey and Nigeria. It also highlights a growing but uneven international interest in bridging mathematics education with everyday contexts.

DISCUSSION

This systematic review synthesises findings from 21 empirical studies (2010–2025) on real-life applications in plane geometry teaching. Real-life contextualisation is *associated with* enhanced student engagement and comprehension across studies, yet implementation remains inconsistent due to systemic barriers.

Multiple studies report that teachers have limited conceptual mastery of geometry and frequently rely on rote memorisation (Adolphus, 2011; Kpotosu et al., 2024). Pre-service teachers also struggle with basics such as area-perimeter distinctions (Atta & Bonyah, 2023). Nine surveyed studies link this to students' weak foundations, creating secondary-level gaps (Odoh et al., 2023). As one Nigerian study pointed out (Adolphus, 2011), when teachers themselves have shaky foundations, it is nearly impossible for them to build a solid understanding in their students. The problem is not just about content knowledge. Too many teachers default to rote memorisation techniques because they have not been trained in more engaging methods such as real-life applications. This deficiency not only diminishes students' interest in mathematics but also leads to poor achievement in advanced topics such as geometry at the secondary level. . In Ghana, studies such as Taley (2022) and Mensah and Nabie (2021) demonstrated that the effective use of technology and diversified instructional methods could significantly improve student performance, but only if teachers are sufficiently trained and confident in their application. Even with this, a substantial gap remains in how teachers assess learners when teaching through real-life applications

Quasi-experiments show that training mitigates this: flipped classrooms (Atta & Bonyah, 2023) and GeoGebra PD (Jiang et al., 2023) yield pre-service gains, unlike Ghana and Turkey surveys that reveal persistent unpreparedness (Taley, 2022; Mensah & Nabie, 2021).

Curriculum rigidity, large classes, and resource shortages dominate 12 studies, limiting real-life integration (Wasserman et al., 2023; Bosson-Amedenu, 2017). Ghana (8 studies) reports rote dominance, whereas Nigeria and Turkey's tech trials (Onaifoh & Ekwueme, 2017) report tech dominance. Routine tasks outperform applications (Fletcher, 2010; Arhin et al., 2018), but ICT and context-rich tasks boost motivation when trained (Mensah & Nabie, 2021; Postier, 2021; Karakoç & Alacacı, 2015), highlighting training gaps over design limits. There may be other factors that prevent mathematics teachers from connecting plane geometry to real-life applications, as the review shows that Senior High School mathematics teachers do not fully integrate real-life applications into their studies.

CONCLUSION

This systematic review emphasises the urgent need for the effective integration of real-life applications into the teaching of plane geometry. The findings suggest that, although there is growing scholarly interest in this approach, significant challenges persist. Many educators find it difficult to grasp foundational geometric concepts, often relying on rote memorisation rather than promoting deep understanding. This lack of conceptual mastery not only impairs teachers' effectiveness but also negatively impacts student performance and engagement.

The review underscores the importance of teacher preparedness in implementing innovative pedagogical strategies. Despite advancements in technology and instructional methods, gaps in teacher training remain a substantial barrier to effective geometry instruction. Additionally, the rigidity of the curriculum and large class sizes further complicate efforts to connect mathematical concepts to real-world contexts.

Ultimately, enhancing student understanding and interest in geometry requires a concerted effort to improve teacher education and instructional practices. This involves embracing inquiry-based learning and providing educators with the resources and training needed to effectively integrate real-world applications. Future research should aim to address these gaps and explore the potential of diverse methodologies to foster a more meaningful learning experience in geometry education.

Limitations of the Study

The decision to focus solely on research articles published between 2010 and 2024 may introduce temporal publication bias, as it excludes potentially relevant studies conducted outside this window. Furthermore, restricting the search to English-language publications introduces language bias, potentially omitting valuable insights from non-English sources. Additionally, the exclusive focus on peer-reviewed journal articles overlooks grey literature and unpublished research, potentially leading to an incomplete representation of existing knowledge.

Suggestion for further study:

Subsequent reviews could improve comprehensiveness by including grey literature, such as dissertations, technical reports, conference materials, and ongoing project databases. Broadening the search to non-English databases would also promote greater inclusivity and gather a broader range of perspectives on real-life applications in the field.

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