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OPTIMIZATION OF GEOMETRIC THINKING THROUGH INTERACTIVE WORKSHEETS: A SCOPING REVIEW

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ABSTRAK

Kemampuan *geometric thinking* merupakan aspek penting dalam pembelajaran matematika, terutama dalam mengembangkan keterampilan visualisasi, pemahaman konsep geometris, dan pemecahan masalah. Menggunakan pendekatan *scoping review*, pencarian dilakukan pada basis data kredibel Google Scholar dengan kata kunci "Interactive Worksheets", "Geometric Thinking", dan "Mathematics Education". Dari total artikel yang ditemukan, seleksi dilakukan melalui proses penyaringan abstrak, pembacaan penuh, dan penerapan kriteria inklusi. Hasil penelitian menunjukkan bahwa LKPD interaktif berpotensi mengoptimalkan *geometric thinking* siswa melalui pemanfaatan elemen seperti gamifikasi, visualisasi dinamis, dan latihan interaktif berbasis teknologi. Tren penelitian didominasi oleh desain eksperimen dan pengembangan teknologi, namun terdapat kesenjangan seperti minimnya uji coba jangka panjang, fokus terbatas pada pendidikan dasar, dan penggunaan indikator *geometric thinking* yang belum beragam. Studi ini merekomendasikan penelitian lebih lanjut dengan pendekatan longitudinal, eksplorasi teknologi mutakhir seperti AI dan AR, serta pengembangan LKPD yang relevan untuk berbagai tingkat pendidikan. Studi ini memberikan wawasan komprehensif mengenai potensi LKPD interaktif dalam mendukung pengembangan *geometric thinking*, sekaligus mengidentifikasi tantangan yang perlu diatasi untuk meningkatkan efektivitasnya dalam pembelajaran matematika.

Kata Kunci: *geometric thinking*, LKPD interaktif, pendidikan matematika, *scoping review*, visualisasi geometris

ABSTRACT

Geometric thinking is a crucial aspect of mathematics education, particularly in developing visualization skills, understanding geometric concepts, and problem-solving abilities. Using a scoping review approach, a search was conducted in the credible Google Scholar database with the keywords "Interactive Worksheets," "Geometric Thinking," and "Mathematics Education." The study specifically focused on research conducted in the context of Indonesia to understand the local implementation and outcomes. Articles were selected through abstract screening, full-text reading, and the application of inclusion criteria. The findings indicate that interactive worksheets have the potential to optimize students' geometric thinking through the utilization of elements such as gamification, dynamic visualization, and technology-based interactive exercises. Research trends in Indonesia are dominated by experimental design and technological development, yet gaps persist, including a lack of long-term trials, limited focus on primary education, and insufficient diversity in the indicators of geometric thinking. This study recommends further research employing longitudinal approaches, exploring cutting-edge technologies such as AI and AR, and developing worksheets tailored to various educational levels. This study provides comprehensive insights into the potential of interactive worksheets to

support the development of geometric thinking in the Indonesian context while identifying challenges that need to be addressed to enhance their effectiveness in mathematics education.

Keywords: geometric thinking, geometric visualization, interactive worksheets, mathematics education, scoping review.

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INTRODUCTION

Geometric thinking is a critical cognitive element in mathematics education. It encompasses understanding, visualization, analysis, and manipulation of geometric concepts essential for daily life and various disciplines, including science, technology, engineering, and mathematics (STEM) (Mierluş-Mazilu & Yilmaz, 2024; Ziatdinov & Valles, 2022). In a world increasingly influenced by technology, geometric thinking forms the foundation for spatial problem-solving, which is relevant across applications such as architectural design, graphic technology, and spatial simulations (Zhu & Klapwijk, 2024). Consequently, mastering geometric thinking is not only vital for students' academic success but also for preparing them to face the challenges of the modern workforce.

However, numerous studies indicate that students' geometric thinking abilities, particularly in Indonesia, remain relatively low. One of the primary factors hindering its development is the traditional learning approach, which emphasizes rote memorization and procedures over exploration and conceptual understanding (Asyifa et al., 2024; Hadi & Mariana, 2024). Additionally, the lack of innovative teaching media presents a significant challenge. Geometry is often perceived as difficult due to its abstract nature and the high level of visualization required, making it essential to provide learning tools that bridge the gap between theory and its real-world applications (Korkut & Surer, 2023; Madrazo & Dio, 2020).

In Indonesia, the challenges in developing students' geometric thinking are compounded by several contextual factors. These include limited access to advanced technological resources in some regions, a curriculum that may prioritize procedural knowledge over conceptual depth, and varying levels of teacher preparedness in integrating technology into the classroom (Maharani et al., 2021; Novianti et al., 2024; Saks et al., 2021). Addressing these issues requires tailored solutions that align with the local educational context while leveraging global best practices in mathematics education.

In response to these challenges, the development of technology-based and interactive learning media, such as interactive worksheets (Lembar Kerja Peserta Didik, LKPD), has emerged as a potential solution. Interactive worksheets are designed to actively engage students in the learning process through concrete visualizations, technology-driven tasks, and immediate

feedback (Cirneanu & Moldoveanu, 2024; Nazlidou et al., 2024). The interactive elements of these worksheets enable students to grasp abstract concepts through meaningful learning experiences (Artasari et al., 2024; Mutlu, 2020). Furthermore, interactive worksheets offer flexibility to adjust the difficulty level of tasks to match students' abilities, thus supporting a differentiated learning approach (Andrews et al., 2023; Giyanti & Oktaviyanthi, 2024). In the context of geometry learning, interactive worksheets can aid students in developing visualization skills, understanding spatial relationships, and solving geometric problems both independently and collaboratively.

Research has consistently demonstrated the effectiveness of interactive media in enhancing learning outcomes, including geometric thinking skills. For instance, studies show that the use of software like GeoGebra or technology-based interactive modules can improve students' understanding of complex geometric concepts (Dereje, 2023; Gurmu et al., 2024; Weinhandl et al., 2020). However, in the Indonesian context, research has primarily focused on specific aspects, such as the application of particular technologies or specific student groups, often within small-scale experimental settings (Hadi & Mariana, 2024; Muchlis et al., 2021; Salsabila et al., 2024). These limitations make it challenging to generalize findings and fully understand the impact of interactive worksheets on students' geometric thinking across diverse educational settings in Indonesia.

METHODS

Literature Identification

The first step in this scoping review methodology involved identifying literature relevant to the research topic, *"Optimizing Geometric Thinking through Interactive Worksheets."* The identification process began by determining search keywords encompassing various terms and phrases related to the study's main themes (Churruca et al., 2021; Pham et al., 2014; Thomas et al., 2020). The keywords used included:

1. **"Interactive worksheets"** to capture literature discussing the use of interactive worksheets in education.
2. **"Geometric thinking"** to focus the search on articles relevant to developing geometric thinking skills.
3. **"Interactive LKPD"** to ensure selected articles focus on interactive, worksheet-based learning media, particularly within the context of education in Indonesia.
4. **"Mathematics education"** to broaden the search within the field of mathematics education.
5. **"Learning media"** to locate studies addressing various types of interactive learning media, including worksheets, used in mathematics education.

Once the keywords were established, searches were conducted on credible and relevant academic databases. Google Scholar was primarily utilized, focusing on publications in Indonesia to ensure access to indexed journals with peer-reviewed articles.

Articles were sourced from national journals, published in either English or Indonesian, to accommodate both local and international literature. Exclusion criteria were employed to filter out articles that solely discussed worksheets without interactive elements and those that did not explicitly mention geometric thinking.

Study Selection

The study selection process was conducted in two stages to ensure the quality and relevance of the selected articles.

1. **Stage 1: Abstract Screening**
   Abstracts of identified articles were reviewed to evaluate their relevance to the research topic. Articles deemed irrelevant based on their abstracts were excluded. This step was essential to reduce the number of articles not aligned with the primary focus of the study (Chai et al., 2021; Wang et al., 2020).
2. **Stage 2: Full-Text Review**
   Articles that passed the abstract screening were subjected to a comprehensive review to determine whether they fully met the inclusion criteria. Articles deemed unsuitable after a full reading were excluded from further analysis (Chai et al., 2021; Wang et al., 2020). Reference management software Mendeley was used to organize the articles and assist in filtering based on metadata and keywords.

Data Extraction

After study selection, the next step was data extraction, which involved collecting key information from each selected article. The extracted data included:

1. **Authors and year of publication**, providing insights into the research background and the temporal and geographical distribution of relevant studies.
2. **Research focus**, detailing the primary topics of each study, such as the use of interactive worksheets, enhancement of geometric thinking, or technology-based learning media design.
3. **Research design**, including whether the studies used experimental methods, case studies, or quantitative/qualitative approaches, as well as the strategies employed in developing interactive worksheets.
4. **Population or subjects**, identifying the student groups involved (e.g., elementary, junior high, or senior high school students) and the educational contexts applied.
5. **Key findings**, summarizing results related to the impact of interactive worksheets on students' geometric thinking and factors influencing these outcomes, such as the type of worksheet used or the teaching methods employed.

Data Analysis

Once the data were extracted, analysis was performed to identify patterns, trends, and gaps in the collected literature (Ewusie et al., 2020; Khitous et al., 2020). This process began with literature mapping, categorizing articles based on the main themes emerging from the studies. The themes analyzed included:

1. **Development methods of interactive worksheets**, encompassing the types of worksheets developed and the methods employed in their creation.
2. **Indicators of geometric thinking measured**, such as spatial visualization abilities, understanding of geometric relationships, and problem-solving skills related to interactive worksheet use.

3. **Outcomes of worksheet implementation**, focusing on improvements in students' abilities and challenges faced during the application of interactive worksheets in classrooms, such as time or resource constraints.

By concentrating on studies conducted in Indonesia, this research provides a focused perspective on how local educational practices and challenges influence the development and implementation of interactive worksheets. The findings aim to contribute to a deeper understanding of the potential and limitations of interactive worksheets in supporting geometric thinking within Indonesia's educational landscape.

RESULT AND DISCUSSION

Overall, the research process is outlined in the flowchart Figure 1. This diagram illustrates the steps undertaken to identify, screen, and include relevant articles based on predetermined criteria. The process begins with the identification of articles through database searches, followed by an initial screening based on abstracts and titles, and proceeds to a thorough evaluation of full-text articles. Throughout this process, discussions and agreements among researchers ensure that only articles meeting the research criteria are included in the final analysis.

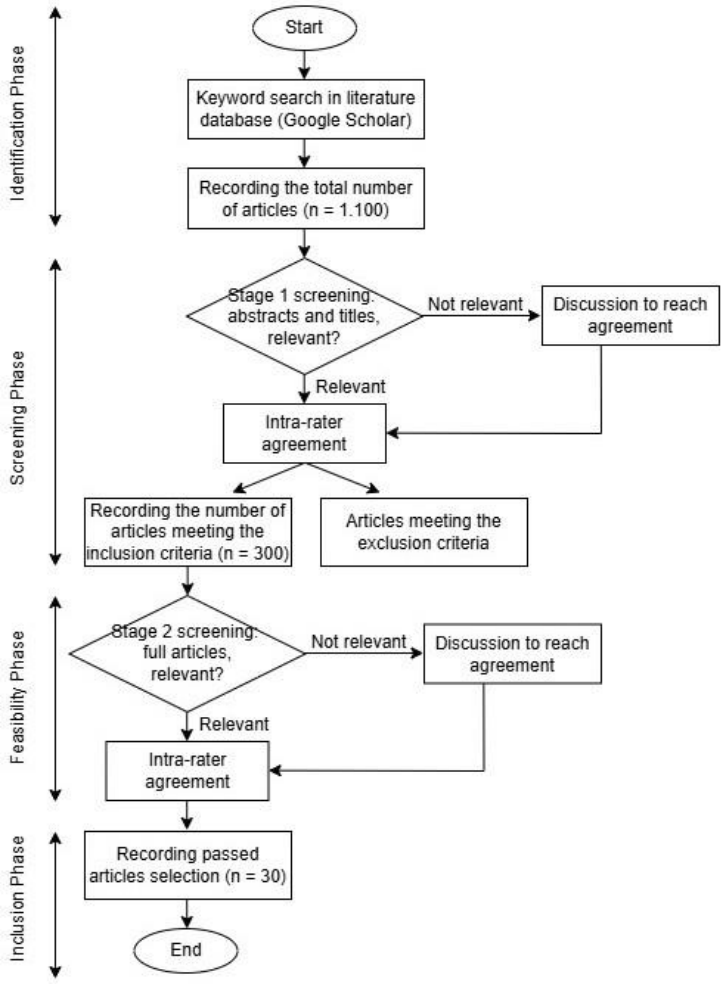

Figure 1. Steps of Scoping Review Screening and Inclusion

Literature Identification

The identification process employed a structured search method using specific keywords such as “Interactive Worksheets,” “Geometric Thinking,” and “Mathematics Education.” Searches were conducted using the Google Scholar database. This process yielded 30 articles, which were screened based on relevance, peer-review status, and conformity to the inclusion criteria.

The temporal and geographical analysis revealed a significant increase in studies on interactive worksheets over the last five years, with a predominant geographical distribution in Western Indonesia. Most studies focused on experimental design and development research, as summarized in Table 1.

Table 1. Research trends by geographic and temporal distribution

No.	Year of Publication	Region	Number of Studies	Research Design
1.	2024	Western Indonesia	10	Development Research
2.	2023	Eastern Indonesia	5	Quasi-Experiment
3.	2022	Western Indonesia	9	Development Research
4.	2021	Northern Indonesia	4	Quasi-Experiment
5.	2020	Eastern Indonesia	2	Development Research

Table 1 illustrates the distribution of studies on interactive worksheets by year of publication, geographical location, the number of studies conducted, and research design type. The data demonstrate an increasing trend in research over the past five years, peaking in 2022 and 2024 in Western Indonesia (9 and 10 studies, respectively), with a dominance of development research. This growth reflects increasing attention to interactive worksheets as innovative educational media in mathematics, particularly for enhancing students' geometric thinking.

Study Selection

The selection process involved abstract and title screening, followed by full-text reading. From an initial pool of 300 articles, 30 met the criteria for further analysis. These studies highlighted the use of interactive elements such as gamification, instant feedback, and dynamic visualization, directly associated with improving geometric thinking skills.

The selection results indicated that technology-based approaches had a more significant impact compared to traditional methods. Technologies such as web-based applications, e-learning platforms, and virtual reality (VR) were the primary tools used to develop interactive worksheets.

Data Extraction and Method Analysis

Data extraction was conducted to map the key elements in the development of interactive worksheets. Research focuses included the interactive elements used, the technology applied,

and the impact on geometric thinking indicators such as spatial visualization, geometric concept understanding, and problem-solving skills.

Table 2. Methods and designs of interactive worksheets in related studies

No.	Worksheet Development Method	Interactive Elements Used	Technology Applied	Measured Geometric thinking Indicators
1.	Web-Based Development	Gamification, 3D Visualization	Web Application	Spatial Visualization, Geometric Concept Understanding
2.	Development Research	Interactive Exercises, Instant Feedback	Mobile Applications	Geometric Problem-Solving Skills
3.	Experimental Research	Interactive Questions, Group Discussions	E-learning Platforms	Geometric Relationship Understanding
4.	Experimental Research	Feedback, Dynamic Visualization	Virtual Reality (VR)	Spatial Visualization, Geometric Problem-Solving Skills

Table 2 summarizes the methods for developing interactive worksheets, interactive elements employed, technologies applied, and geometric thinking indicators measured in related studies. The use of technologies, including web-based applications, mobile devices, e-learning platforms, and VR, was prominent. Analysis revealed that specific interactive elements, such as dynamic visualization and gamification, had a significant impact on improving students' geometric skills. VR technology, in particular, enabled effective exploration of complex spatial concepts compared to traditional media.

Impact on Geometric Thinking

The impact of using interactive worksheets on geometric thinking was analyzed from various aspects. Most studies reported significant improvements in spatial visualization skills, understanding geometric relationships, and problem-solving abilities. These findings support the role of interactive worksheets in accelerating the mastery of geometric concepts.

Table 3. Impact on geometric thinking

No.	Type of Interactive Worksheet	Impact on Geometric Thinking	Key Findings
1.	Web-Based Worksheet with Gamification	Improved spatial visualization	Enhanced 3D visualization and understanding of geometric relationships
2.	Mobile Worksheet with Instant Feedback	Improved geometric problem-solving	Interactive questions facilitated faster and more accurate problem-solving
3.	E-learning Worksheet with Dynamic Visualization	Improved understanding of geometric concepts	Dynamic visualization supported better comprehension of complex geometric concepts
4.	VR-Based Worksheet	Improved spatial visualization and problem-solving skills	VR effectively facilitated understanding of spatial relationships and improved problem-solving skills

Table 3 presents the types of interactive worksheets used in the studies and their impact on geometric thinking, such as spatial visualization, concept understanding, and problem-

solving. Each type of worksheet demonstrated specific benefits, with web-based worksheets excelling in spatial visualization and mobile worksheets showing significant results in problem-solving. VR-based worksheets provided immersive learning experiences, showing great potential for advanced geometric exploration.

Research Gaps

Despite the positive results, several gaps were identified:

1. **Educational Level:** Studies predominantly focused on secondary education, with limited attention to primary levels.
2. **Study Duration:** Most studies were short-term, limiting the understanding of long-term impacts.
3. **Advanced Technologies:** The use of technology was mainly restricted to web applications and e-learning, with minimal exploration of AI or AR.

Table 4. Research gaps and recommendations

Research Gap	Description	Recommendations
Limited studies at primary education level	Most studies focus on secondary or higher education, with few addressing primary levels	Further research is needed at the primary education level
Lack of long-term studies	Majority of studies are short-term	Long-term studies are required to measure sustained impact of interactive worksheets
Limited use of advanced technologies	Studies mostly use basic technologies like web applications or e-learning	Future research should explore advanced technologies like AI and AR to enrich learning experiences
Narrow range of measurement indicators	Indicators measured are limited to visualization and problem-solving	Broader indicators for measuring geometric thinking should be adopted

Table 4 highlights key gaps in the literature on interactive worksheet research, including educational levels, study duration, and the adoption of advanced technologies. Most studies focused on secondary or higher education, leaving primary education underexplored. Short-term studies constrained insights into long-term effects. Future research should explore cutting-edge technologies like AI and AR for richer, adaptive learning experiences and expand the range of geometric thinking indicators to achieve a more comprehensive understanding.

Discussion

Research Trends

Based on the analysis of the geographical and temporal distribution of studies, there is noticeable variation in the intensity and location of research concerning interactive worksheets that support geometric thinking. The distribution table indicates that studies on this topic have experienced significant growth over the past five years, with a primary focus in Indonesia. Research in Western Indonesia tends to employ more advanced technology in the design of interactive worksheets.

In terms of research design, experimental studies and development research dominate, reflecting a practical approach to measuring the effectiveness of interactive worksheets in

enhancing geometric thinking skills (Gurmu et al., 2024; Simeon et al., 2020). However, there is a noticeable lack of longitudinal studies that could provide long-term insights into the impact of worksheet-based learning.

Methods and Designs of Interactive Worksheets

The mapping of interactive elements in worksheets reveals that elements such as gamification, interactive exercises, and dynamic visualization are commonly used to enhance students' learning experiences (Chen et al., 2023; Purgina et al., 2019). A diagram mapping the technologies used shows a preference for web-based and mobile applications to support student engagement.

The studies also suggest that technology-based designs, such as Virtual Reality (VR) and instant feedback elements, have great potential in enhancing students' spatial visualization skills (Korkut & Surer, 2023; Safadel & White, 2020). However, the lack of infrastructure and availability of technology in some regions presents a barrier to the widespread implementation of these methods.

Impact on Geometric Thinking

The analysis of the primary research outcomes indicates that the use of interactive worksheets has a notable positive impact on various aspects of geometric thinking. Studies that utilized dynamic visualization and technology-based exercises have substantially improved students' spatial visualization skills (Ali et al., 2024; Kohen et al., 2022).

Additionally, students using worksheets with gamification elements tend to be more motivated to understand complex geometric concepts. Comparison graphs show that the majority of studies report significant improvements in geometric problem-solving skills, particularly when interactive technologies are applied.

Research Gaps

The analysis also uncovered several gaps in the existing literature. First, the majority of studies focus on secondary education, with limited research at the primary or higher education levels. However, the development of geometric thinking at an early age could have a more profound impact on students' mathematical abilities (ÖZÇAKIR et al., 2020; Schoevers et al., 2020).

Second, short-term studies dominate the literature, meaning there is a lack of long-term evidence regarding the effectiveness of interactive worksheets. This is a significant limitation. Furthermore, the variety of measurement indicators is still limited to spatial visualization and problem-solving, with other indicators such as geometric connections or mathematical reasoning not yet widely explored.

To fill these gaps, further research is needed that employs longitudinal designs and incorporates advanced technologies like Artificial Intelligence (AI) or Augmented Reality (AR) to expand the potential applications of interactive worksheets. These advancements could offer new dimensions for exploring geometric thinking and enhance the learning experience for students, particularly in regions where access to cutting-edge technology is improving.

CONCLUSION

The findings of this study indicate that interactive worksheets play a substantial role in the development of students' geometric thinking skills through elements such as gamification, dynamic visualization, and technology-based exercises. These elements have a positive impact on spatial visualization, understanding of geometric concepts, and problem-solving abilities. The research trends are dominated by experimental and development approaches based on technology, particularly in Western Indonesia. However, there are gaps, such as the lack of long-term studies, limited focus on primary education, and the restricted variety of geometric thinking indicators used.

This study has several limitations, such as the restricted database used, the geographic focus that does not fully represent the global context, and the exploratory nature of the scoping review approach. Additionally, the variety of technologies explored is still limited to certain technology-based approaches.

Future research is recommended to conduct longitudinal studies to assess the long-term impact of interactive worksheets, expand the focus to include primary education, and explore the use of cutting-edge technologies such as Artificial Intelligence (AI) and Augmented Reality (AR). Furthermore, the indicators of geometric thinking should be broadened to include aspects such as geometric reasoning and real-world applications. Cross-cultural research is also needed to understand the influence of social and cultural factors on the effectiveness of interactive worksheets. By addressing these limitations, interactive worksheets can continue to evolve as an effective and relevant learning tool across diverse educational contexts, including those in Indonesia, where recent advancements in digital learning technology are being increasingly explored.

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