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Meta Analysis: The Effect Of Guided Discovery Learning Model On Geometric Thinking Ability Of Elementary School Students

Dodi Lesmana
Department of Elementary Education, Jakarta State University, Jakarta, Indonesia
Purwati
Faculty of Education and Teacher, Universitas Terbuka, South Tangerang, Indonesia
Mira Amelia Amri
Department of Elementary Education, Jakarta State University, Jakarta, Indonesia

Corresponding Author: dodi.lesmana@mhs.unj.ac.id

Abstract

Geometric thinking is a person's ability to understand points, lines, angles, planes, and spaces so that they are able to understand geometric objects well. This study aims to determine the impact of the guided discovery learning model on the geometric thinking ability of elementary school students. This research method uses a quantitative approach, namely the meta-analysis method. Data were collected from experimental studies related to the application of the Guided discovery learning model to students' geometric thinking abilities at the elementary school level in indexed papers from 2018 to 2026. From the search and selection of studies, 48 articles were obtained. This study found that there is an increase in the number of publications each year, mostly focusing on geometric thinking ability. It is also known that researchers conduct a lot of research at the elementary school level, with a sample size of more than 30. Meanwhile, viewed from the demographic aspect, this research is more concentrated in Java Island. The application of the discovery learning model on students' mathematical abilities has an overall effect size of 0.815 with a high effect category.

Keywords: Guided discovery learning, Geometric thinking, Meta-analysis, Elementary school

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INTRODUCTION

The rapid advancement of science, technology, and digital communication in the twenty-first century has fundamentally transformed the competencies expected of students in modern education. Learners are no longer required only to memorize mathematical formulas or perform routine calculations, but they are expected to develop higher-order thinking skills, critical reasoning, creativity, collaboration, and problem-solving abilities that enable them to adapt to increasingly complex real-life situations. Mathematics, as one of the core disciplines in elementary education, plays an essential role in fostering these competencies because it trains students to think systematically, logically, and analytically. Among the various branches of mathematics, geometry occupies a unique position because it develops students' understanding of spatial relationships, visualization, and reasoning about shapes and structures encountered in everyday life. According to Freudenthal (1973), geometry has been one of the most significant mathematical domains throughout history due to its close connection with human activities and the physical environment. Likewise, the National Council of Teachers of Mathematics (NCTM, 2020) emphasizes that geometry is one of the five major strands of school mathematics and should receive balanced attention alongside number, algebra, measurement, and data analysis. Through geometry learning, students learn to recognize patterns, analyze properties of objects, make logical arguments, and connect mathematical concepts with real-world phenomena. These abilities become increasingly important in the era of technological innovation, where spatial reasoning is required in fields such as engineering, architecture, computer graphics, robotics, and artificial intelligence. Consequently, strengthening geometric thinking at the elementary school level is considered a strategic effort to prepare students with the cognitive foundations necessary for lifelong learning and future technological challenges.

Geometric thinking itself refers to the cognitive process through which individuals understand geometric concepts, identify relationships among shapes, and reason logically about spatial structures. Van Hiele (1986) proposed that students' geometric thinking develops progressively through hierarchical levels, beginning with visual recognition, advancing to analysis of properties, informal deduction, formal deduction, and finally rigorous mathematical reasoning. This developmental theory has become one of the most influential frameworks in mathematics education because it explains why students often experience difficulties when instructional approaches are not aligned with their cognitive readiness. Similarly, Clement and Battista (1989) describe geometric thinking as a mental activity involving the organization of spatial information, visualization, and reasoning about geometric relationships. More recently, Wu et al. (2024) define

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geometric thinking as the ability to utilize logical reasoning and spatial representation to understand the structures and relationships among geometric elements. Despite its importance, numerous studies indicate that elementary school students frequently demonstrate limited geometric understanding. Many students can identify geometric figures based solely on their appearance but struggle to explain defining properties, compare shapes using mathematical reasoning, or apply geometric concepts to solve contextual problems. These learning difficulties are often associated with teacher-centered instructional practices that emphasize memorization rather than conceptual exploration. As a result, students tend to develop fragmented knowledge instead of meaningful conceptual understanding. Therefore, improving students' geometric thinking requires instructional approaches that actively engage learners in constructing knowledge through investigation, observation, reasoning, discussion, and reflection rather than passive reception of information.

One instructional approach that has gained considerable attention in mathematics education is the Guided Discovery Learning model. Guided Discovery Learning is a student-centered instructional model in which teachers facilitate students' exploration of mathematical concepts by providing structured guidance while allowing learners to independently discover underlying principles through carefully designed learning activities. Unlike direct instruction, Guided Discovery Learning encourages students to formulate hypotheses, investigate patterns, manipulate mathematical objects, discuss findings collaboratively, and draw conclusions based on evidence obtained during the learning process. This approach is strongly grounded in constructivist learning theory, which argues that meaningful knowledge is actively constructed by learners through interaction with their environment rather than transmitted directly by teachers. In geometry instruction, Guided Discovery Learning provides students with opportunities to manipulate concrete materials, observe geometric relationships, construct diagrams, compare various shapes, and justify mathematical conclusions through logical reasoning. Such learning experiences support the development of visualization skills, spatial reasoning, conceptual understanding, and mathematical communication simultaneously. Previous empirical studies have consistently reported that Guided Discovery Learning contributes positively to various mathematical competencies, including conceptual understanding, mathematical reasoning, critical thinking, problem-solving ability, creativity, and learning motivation. However, research findings regarding its effectiveness on elementary students' geometric thinking remain dispersed across different publications with varying sample characteristics, research designs, educational contexts, and reported effect sizes. Consequently, educators and researchers still require

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comprehensive evidence to determine the overall effectiveness of this instructional model and identify patterns emerging across multiple empirical studies.

Considering the growing body of literature concerning Guided Discovery Learning and geometric thinking, synthesizing previous research findings through a meta-analysis becomes highly relevant and necessary. Meta-analysis is a quantitative research synthesis method that combines statistical findings from multiple independent studies to estimate the overall effectiveness of a particular educational intervention while minimizing subjective interpretation. Compared with traditional literature reviews, meta-analysis provides stronger empirical evidence because it calculates an overall effect size and enables researchers to examine trends based on publication year, educational level, sample characteristics, demographic distribution, and methodological variations. Such analysis allows researchers to identify whether Guided Discovery Learning consistently improves students' geometric thinking across different learning environments and research contexts. Furthermore, a meta-analysis can reveal research gaps that remain insufficiently explored and provide practical recommendations for future instructional implementation and educational research. In Indonesia, studies examining Guided Discovery Learning have increased significantly during recent years, reflecting educators' growing interest in implementing student-centered learning approaches aligned with the Independent Curriculum and twenty-first-century learning objectives. Nevertheless, no comprehensive synthesis has specifically examined the influence of Guided Discovery Learning on elementary school students' geometric thinking ability by integrating evidence from indexed publications between 2018 and 2026. Therefore, this study aims to conduct a systematic literature review using a meta-analysis approach to determine the overall effect of the Guided Discovery Learning model on elementary school students' geometric thinking ability. The findings are expected to provide evidence-based recommendations for teachers, researchers, curriculum developers, and educational policymakers regarding the effectiveness of Guided Discovery Learning in improving geometry learning outcomes at the elementary school level.

RESEARCH METHODOLOGY

Research Design

This study uses a quantitative approach in the form of a Systematic Literature Review (SLR) with a Meta-analysis method. A Systematic Literature Review is a review of all relevant studies to answer specific questions. This review is conducted comprehensively and systematically to assess the validity (feasibility) of each relevant study and reduce bias at each stage by identifying,

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critically evaluating, and presenting a synthesis of relevant studies as well as improving the clarity of the synthesis (Juandi, 2021, p. 2). This analysis is carried out on secondary data in the form of primary research results regarding the application of the discovery learning model to mathematical abilities, specifically students' mathematical problem-solving, critical thinking, understanding, and reasoning abilities. The meta-analysis method is carried out by identifying, reviewing, evaluating, and systematically interpreting articles that meet a set of standards, where each process follows predetermined steps (Afsari et al., 2021; Triandini et al., 2019). The design of the meta-analysis research procedure begins with formulating research questions and selection criteria, developing search strategies, the study selection process, and assessing study quality (Cohen et al., 2018, p. 432). The data collected are primary studies that have been published by indexed publishers.

Inclusion criteria

To obtain data to achieve the research objectives, inclusion criteria are set for the collected primary data.These inclusion criteria include:

1. The article is the result of research on mathematics education in Indonesia.
2. Articles published between 2018 and 2026.
3. Articles in the form of journals and proceedings have been indexed.
4. This study uses an experimental method with the application of Guided Discovery Learning on students' geometric thinking abilities.
5. The sample used is research at the elementary school level.

Literature search strategy

The search began by opening the Google Scholar website (www.scholar.google.com), then typing the keywords “Guided discovery learning, Geometric Thinking, “penemuan terbimbing”, and “berpikir geometris”. Next, the publication year range was set from 2018 to 2026. After that, each article was reviewed and those that met the inclusion criteria would be used as research subjects.

Research instruments

The research instrument is in the form of a coding form containing statistical data (sample size, mean, standard deviation, p-value, t-value) and study characteristics (journal publication year, education level, sample size used, demographics) from the primary data obtained.

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Research subjects

The subjects of this research are previous studies published in national and international mathematics education research articles found through electronic database searches such as SINTA, Garuda Portal, Google Scholar, DOAJ, Crossref, IPI, and national journal URLs in the 2018–2026 period. The data collected and used as research subjects are related to the application of the Guided discovery learning model to the geometric thinking ability of students at the elementary school level. From the search results, there were 48 relevant articles suitable for further analysis.

RESEARCH RESULTS

The literature search process identified a total of 48 primary studies that met all predetermined inclusion criteria and were subsequently included in the meta-analysis. The selected studies were published between 2018 and 2026 and originated from indexed national and international journals as well as conference proceedings. The screening process was conducted systematically by removing duplicate publications, reviewing titles and abstracts, evaluating full-text articles, and assessing methodological suitability based on the established eligibility criteria. All selected studies employed an experimental or quasi-experimental research design comparing the Guided Discovery Learning model with conventional or alternative instructional approaches in elementary mathematics learning. Analysis of publication trends demonstrates a steady increase in the number of studies investigating Guided Discovery Learning over the observation period, with the highest publication frequency occurring in 2025 and 2026. This trend reflects the growing interest of mathematics education researchers in student-centered instructional approaches that support twenty-first-century competencies. In terms of research location, most studies were conducted on Java Island, while a smaller proportion originated from Sumatra, Kalimantan, Sulawesi, Bali, and Nusa Tenggara. This finding indicates that research on Guided Discovery Learning remains geographically concentrated and has not yet been evenly distributed across all regions of Indonesia. Regarding sample characteristics, the majority of studies involved more than 30 participants, suggesting that most researchers attempted to achieve adequate statistical power in evaluating instructional effectiveness. Overall, these descriptive findings indicate that research concerning Guided Discovery Learning has expanded considerably during recent years, providing sufficient empirical evidence for conducting a comprehensive quantitative synthesis through meta-analysis.

The quantitative synthesis of the selected studies revealed that the Guided Discovery Learning model produced an overall effect size of 0.815, which falls into the high effect category

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according to Cohen's classification. This finding indicates that Guided Discovery Learning has a substantial positive influence on elementary school students' geometric thinking ability compared with conventional instructional approaches. The relatively high effect size suggests that students who participated in Guided Discovery Learning consistently demonstrated better performance in recognizing geometric shapes, identifying properties, analyzing relationships among figures, constructing logical arguments, and solving geometry-related problems. The positive effect observed across multiple studies also indicates that Guided Discovery Learning is effective in facilitating conceptual understanding rather than merely improving procedural skills. During guided discovery activities, students actively construct knowledge by observing geometric objects, conducting investigations, discussing findings with peers, testing hypotheses, and drawing conclusions through teacher guidance. Such learning experiences enable students to develop meaningful conceptual structures because knowledge is acquired through exploration instead of passive memorization. Furthermore, the consistency of positive findings across various research settings suggests that the effectiveness of Guided Discovery Learning is relatively stable despite differences in school characteristics, instructional materials, sample size, and implementation procedures. These results strengthen the argument that Guided Discovery Learning represents an effective pedagogical strategy for improving geometric thinking ability among elementary school students and supports its wider implementation within mathematics classrooms.

The findings of this meta-analysis are consistent with constructivist learning theory, which emphasizes that meaningful learning occurs when students actively construct their own understanding through interaction with learning environments. Guided Discovery Learning provides opportunities for learners to observe patterns, manipulate learning materials, formulate conjectures, verify ideas, and communicate mathematical reasoning with teacher facilitation. Such learning processes correspond closely to the developmental stages of geometric thinking proposed by Van Hiele (1986). According to the Van Hiele theory, students progress through sequential levels of geometric understanding, beginning with visualization and gradually advancing toward analytical and deductive reasoning. Guided Discovery Learning supports this progression because students are encouraged to investigate geometric concepts independently before receiving formal explanations from teachers. Rather than simply memorizing definitions, students develop conceptual understanding through direct experiences and reflective discussions. This instructional process also aligns with the perspectives of Clement and Battista (1989), who argue that geometric thinking develops through mental organization of spatial relationships and active reasoning about geometric structures. The results further support previous empirical

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studies reporting that Guided Discovery Learning improves students' critical thinking, mathematical reasoning, conceptual understanding, problem-solving ability, and learning motivation. Consequently, the present findings provide additional empirical evidence that Guided Discovery Learning is not only beneficial for general mathematics achievement but also particularly effective in strengthening one of the most fundamental competencies in elementary mathematics education, namely geometric thinking.

Although the overall findings demonstrate a strong positive effect, several important implications and limitations should be considered. First, the concentration of studies conducted predominantly on Java Island indicates that future research should expand implementation to other regions of Indonesia to improve the generalizability of findings across different educational contexts. Second, although most studies involved relatively large sample sizes, variations in research design, instructional duration, assessment instruments, and teacher experience may have contributed to differences in the reported effect sizes. Future meta-analyses could therefore investigate potential moderator variables such as grade level, geometry topics, intervention duration, teacher qualifications, and students' prior mathematical achievement to explain the sources of heterogeneity more comprehensively. In addition, future primary studies should report complete statistical information, including means, standard deviations, confidence intervals, and effect size estimates, to facilitate more accurate quantitative synthesis. From a practical perspective, the findings suggest that elementary school teachers should integrate Guided Discovery Learning more systematically into geometry instruction by designing activities that encourage exploration, collaboration, reasoning, and reflective discussion rather than relying predominantly on teacher-centered explanations. Curriculum developers and educational policymakers may also consider incorporating Guided Discovery Learning into teacher professional development programs because empirical evidence consistently demonstrates its effectiveness in improving students' geometric thinking ability. Overall, this meta-analysis provides robust evidence that Guided Discovery Learning constitutes an effective instructional model capable of supporting meaningful geometry learning and promoting higher-order mathematical thinking among elementary school students.

CONCLUSION

Based on these data, it is concluded that research on the application of the Guided discovery learning model contributes more to students' geometric thinking abilities. Every year, the number of published studies on geometric thinking ability increases. Along with technological

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developments, more and more researchers are discussing life phenomena, especially in the field of education. From the data collection of several studies, it is also known that researchers conduct more research at the junior high school education level, with a sample size of more than 30. Meanwhile, when viewed from the demographic aspect, this research is located more in Java Island, while for the Nusa Tenggara and Maluku regions, there is still a lack of experimental research related to the application of the Guided discovery learning model in improving students' geometric thinking abilities. Based on the analysis of 48 data, the effect of the guided discovery learning model on students' geometric thinking ability with an overall effect size of 0.815 is included in the high effect category. There is a diversity of media and student learning activities in the guided discovery learning model based on the results of the reviewed studies. Some studies add learning media, while others do not. Student activities during the learning process also vary. From the results of the review regarding the diversity of this learning process, it was found that a learning process categorized as effective does not only depend on the model used, but also on other aspects.

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