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Didactic Design Research in Overcoming Epistemological Barriers in Mathematics Learning; A Systematic Literature Review

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Abstract
Epistemological obstacles are among the primary factors that impede students' understanding of mathematical concepts. Didactical Design Research (DDR) emerges as a learning-obstacle-based approach that offers a systematic framework for identifying and addressing these barriers. However, comprehensive reviews mapping DDR research trends in the context of epistemological obstacles in mathematics education remain limited. This study aims to: (1) analyze trends in DDR research on epistemological obstacles, (2) identify the most prevalent types of epistemological obstacles, (3) map the didactic design strategies employed, and (4) assess the effectiveness of DDR implementation. A Systematic Literature Review (SLR) following the PRISMA protocol was conducted. Articles were retrieved from Google Scholar, ERIC, and Sinta databases covering 2015–2025. After rigorous selection, 27 articles met the inclusion criteria. Findings indicate that: (1) DDR research has grown significantly from 2020 to 2025, particularly at the junior and senior secondary levels; (2) dominant epistemological obstacles involve difficulties in abstract concept comprehension, symbolic misconceptions, and failure to transfer concepts; (3) effective didactic strategies include mathematical visualization, contextual scaffolding, reflective discussion, and structured cognitive conflict; and (4) consistent DDR implementation demonstrably improves students' conceptual understanding. These findings carry strategic implications for developing adaptive, obstacle-informed mathematics learning designs.

Keywords: Didactical Design Research; epistemological obstacles; mathematics education; systematic literature review; learning obstacle

INTRODUCTION

Mathematics is a discipline characterized by its abstract, hierarchical, and deductive nature, which demands a high level of logical and conceptual thinking (Nurhasanah, Pramudya, & Riyadi, 2021). In educational practice, the learning difficulties experienced by students are not solely caused by individual cognitive factors but also by obstacles rooted in the limitations of knowledge construction within specific contexts. One form of obstacle that has been theoretically recognized in mathematics education is the epistemological obstacle—a condition in which students' knowledge functions only within the specific context in which it was constructed, thereby preventing its flexible application to new situations (Brousseau, 1997).

Epistemological barriers often manifest themselves in the form of misconceptions, repeated procedural errors, and a failure to transfer concepts across mathematical topics. This situation is highly relevant to the low level of conceptual understanding among Indonesian students, as reflected in PISA and TIMSS results, which consistently place Indonesia below the average of participating countries (OECD, 2023). Therefore, a pedagogical approach is needed that does not merely teach procedures but is capable of systematically identifying and addressing the root causes of learning barriers.

Didactical Design Research (DDR) emerged as a response to this need. DDR is an educational research approach developed by Suryadi (2010) that focuses on the design, implementation, and reflection of instructional design based on the identification of students' learning obstacles. DDR enables educators to design adaptive didactic scenarios through anticipatory thinking and the reconstruction of didactic situations based on empirical findings in the field. This approach treats epistemological barriers not merely as problems, but as a starting point for meaningful instructional design.

Since its introduction, DDR-based research has developed rapidly in the context of mathematics education in Indonesia and internationally. Various studies have been conducted on topics such as geometry, algebra, functions, numbers, and mathematical abstraction. However, the results of these studies remain scattered across various publications and have not yet been comprehensively synthesized. Studies that specifically map DDR's contributions to overcoming epistemological barriers—including research trends, the types of barriers identified, didactic design strategies, and evidence of their effectiveness—remain very limited (Juhaevah et al., 2025; Riastuti, Juandi, & Suryadi, 2023).

This gap in the literature forms the basis for the urgency of this study. Using a Systematic Literature Review (SLR) approach in accordance with the PRISMA protocol, this study aims to produce a comprehensive synthesis of the role of DDR in overcoming epistemological barriers in mathematics learning. This study is expected not only to make a theoretical contribution to the field of mathematics education but also to provide an empirical foundation for teachers, researchers, and curriculum developers in designing mathematics instruction that is more effective, contextual, and oriented toward students' learning needs.

Based on the above discussion, the research questions in this study are: (1) What are the trends in DDR research regarding the overcoming of epistemological barriers in mathematics learning? (2) What are the most dominant forms of epistemological barriers found? (3) What didactic design strategies have been developed through DDR? (4) To what extent is the implementation of DDR effective in improving students' understanding of mathematical concepts?

METHOD

Research Design

This study employed a Systematic Literature Review (SLR) design in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol. This method was chosen because it produces a scientific synthesis that is systematic, transparent, and reproducible, and avoids the selection bias that often occurs in conventional narrative reviews (Page et al., 2021). The SLR protocol in this study comprises four main stages: identification, screening, eligibility assessment, and inclusion.

Data Sources and Search Strategy

A systematic search for articles was conducted using three primary databases: Google Scholar, ERIC (Education Resources Information Center), and the Sinta (Science and Technology Index) portal of indexed national journals. These databases were selected due to their relevance to the research topic and their broad coverage of both national and international mathematics education literature.

The search used a combination of keywords in Indonesian and English, namely: "Didactical Design Research," "epistemological obstacle," "learning obstacle," "hambatan epistemologis," "didactic design," and "mathematics education." The Boolean operators AND, OR, and quotation marks were used to refine the relevance of the search results. The search was limited to the years 2015–2025 to ensure the literature was up-to-date.

Inclusion and Exclusion Criteria

Table 1. Article Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Time Range	2015–2025	Before 2015
Language	Indonesian and English	Other than Indonesian/English
Topic	DDR and epistemological barriers in mathematics learning	Does not discuss DDR or epistemological barriers
Publication type	Peer-reviewed journal articles and reputable conference proceedings	Books, theses, and non-peer-reviewed papers
Accessibility	Full text available	Abstract only or not accessible

Article Selection Process

The identification process yielded 312 initial articles from the three databases. After removing duplicates, 241 articles remained, which underwent a screening stage based on titles and abstracts. A total of 189 articles were eliminated because they did not meet the topic relevance criteria. Of the 52 articles that passed the screening, a thorough eligibility assessment based on the full text was conducted, and 25 articles were excluded because they did not specifically address DDR or did not include an analysis of epistemological barriers. Ultimately, 27 articles met all inclusion criteria and were used in the synthesis.

Data Analysis Techniques

The data were analyzed using descriptive qualitative content analysis techniques. The extracted information included: (1) publication details (author, year, journal, country), (2) the grade level and mathematics content examined, (3) the types of epistemological barriers identified, (4) the didactic design strategies implemented, and (5) the outcomes/effectiveness of DDR implementation. The extracted data were then coded, categorized, and synthesized to identify research patterns and trends. The validity of the study was ensured through inter-researcher triangulation and an audit trail of all selection stages.

RESULTS AND DISCUSSION

Trends in DDR Research in Overcoming Epistemological Barriers

An analysis of the 27 articles that met the inclusion criteria revealed significant progress in DDR research based on epistemological barriers, particularly during the 2020–2025 period (n=19; 70.4%). This phenomenon indicates that the mathematics education research community is increasingly recognizing the importance of systematically integrating the analysis of learning barriers into instructional design, in line with the growing adoption of the DDR framework developed by Suryadi (2010) in various educational institutions across Indonesia.

In terms of educational levels, most DDR research was conducted at the junior high school level (n=12; 44.4%) and senior high school level (n=8; 29.6%), followed by elementary school (n=4; 14.8%) and higher education (n=3; 11.1%). This dominance of the secondary levels can be explained by the high complexity of mathematical concepts at those levels as well as the higher frequency of epistemological barriers in transitional topics such as introductory algebra and transformational geometry (Pauji et al., 2023). The distribution of the mathematics topics examined was dominated by algebra (n=9), geometry (n=8), functions (n=5), numbers (n=3), and other topics (n=2).

Table 2. Distribution of Mathematics Content in the DDR Study

Mathematics Topics	Number of Studies (n)	Percentage (%)	Dominant Grade Level
Algebra	9	33.3%	Junior High/High School
Geometry	8	29.6%	Junior High/High School
Functions	5	18.5%	High School/College
Numbers & Fractions	3	11.1%	Elementary/Middle School
Other	2	7.4%	Various

Dominant Forms of Epistemological Barriers

A synthesis of the findings from 27 articles identified four main categories of epistemological barriers in mathematics learning. First, difficulties in understanding abstract concepts (n=22; 81.5%), which include students' inability to distinguish formal definitions from naive intuitions, particularly regarding functions, limits, and geometric transformations. Second, symbolic and procedural misconceptions (n=19; 70.4%), in which students manipulate symbols mechanically without understanding their semantic meaning—for example, treating the equals sign as a procedural operator rather than an equivalence relation.

Third, failure to transfer concepts (n=16; 59.3%), which refers to students' inability to apply concepts they have learned to different contexts or representations. This phenomenon is particularly prominent in the transition from arithmetic to algebra and from concrete geometry to coordinate geometry. Fourth, procedural understanding without a conceptual foundation (n=14; 51.9%), where students are able to execute algorithms but cannot explain the reasoning behind the procedures, leading to failure when faced with variations of problems. These findings are consistent with Brousseau's (1997) theoretical framework regarding the origins of epistemological barriers and are supported by the studies of Herman & Prabawanto (2021) and Munawwaroh et al. (2025).

Didactic Design Strategies in DDR

DDR implementation is carried out through three main, interrelated stages: (1) didactic situation analysis (prospective analysis), which includes identifying learning obstacles through diagnostic tests, observations, , and interviews; (2) the development of a Hypothetical Didactic Design (HDD) based on the findings of the analysis; and (3) a retrospective analysis that compares the planned design with students' actual responses in the field (Suryadi, 2010).

A review of 27 articles identified five clusters of didactic strategies that are most effective in overcoming epistemological barriers. (1) Visualization and multiple representations (82%): the use of visual, concrete, pictorial, and abstract representations, as well as manipulatives, to bridge conceptual abstraction. (2) Contextual scaffolding (74%): providing gradual support based on real-world contexts relevant to students' experiences. (3) Reflective discussions and structured cognitive conflict (67%): designing learning situations that create cognitive conflict between students' prior knowledge and new concepts, which are then facilitated through reflective discussions. (4) Diagnostic and probing questions (63%): the use of questions designed to openly expose and discuss students' misconceptions. (5) Integration of non-routine problem-solving contexts (59%): the presentation of contextual problems that require the transfer of concepts and higher-order mathematical reasoning.

These strategies are not implemented separately but are integrated into a single cohesive instructional design developed specifically for each identified learning obstacle. This finding supports the view of Eka et al. (2024) that the effectiveness of DDR depends heavily on the depth of the analysis of learning obstacles that precedes the design process.

Effectiveness of DDR Implementation

Of the 27 articles reviewed, 24 (88.9%) reported a significant improvement in students' conceptual understanding following the implementation of DDR. This improvement was measured using various instruments, including conceptual understanding tests (n=21), clinical interviews (n=15), classroom observations (n=12), and error analysis (n=10). The effectiveness of DDR was evident not only in improved test scores but also in a reduction in the frequency of conceptual errors documented in retrospective analyses.

Pauji et al. (2023) reported that the implementation of DDR in number-recognition material successfully reduced the identified learning obstacles by 68%. Meanwhile, Pramudya, Mardiyana, & Saputro (2023) found that a DDR-based instructional design increased the N-gain for understanding geometric transformation concepts by 0.58 (moderate-high category) compared to conventional learning. Dela, Mohamad, & Erik (2025) emphasize that an iterative DDR cycle results in more precise design improvements in addressing remaining epistemological barriers.

Nevertheless, several limitations should be noted. Most studies (n=18; 66.7%) were conducted as small-scale classroom action research with limited samples, so the findings should be generalized with caution. Only 6 articles (22.2%) used comparative or quasi-experimental designs that allow for stronger claims of causality. This suggests that future DDR research needs to shift from descriptive-exploratory studies toward research designs that are more methodologically rigorous.

CONCLUSION

Based on the results of a systematic literature review of 27 DDR research articles in the context of epistemological barriers in mathematics learning, four main conclusions can be drawn. First, DDR research experienced significant growth from 2020 to 2025, particularly at the junior high and high school levels, with a dominant focus on algebra and geometry. Second, the most frequently identified epistemological barriers were difficulty understanding abstract concepts, symbolic misconceptions, failure to transfer concepts, and procedural understanding lacking a conceptual foundation. Third, the most effective didactic strategies include multiple visualizations, contextual scaffolding, structured cognitive conflict, probing questions, and the integration of non-routine problems. Fourth, the consistent implementation of DDR has been shown to improve students' conceptual understanding and reduce learning obstacles, although most studies are still small-scale.

Theoretically, this study reinforces the role of DDR as a research and instructional development framework that is highly relevant for addressing epistemological barriers. Practically, these findings provide evidence-based guidance for teachers in designing mathematics instruction that is more adaptive and responsive to students' learning barriers.

Recommendations

Based on the findings of this study, several recommendations can be made. For teachers and education practitioners, it is recommended that they proactively adopt the DDR framework in instructional design, particularly by strengthening their competencies in conducting didactic situation analysis and developing pedagogical strategies. DDR-based professional development should be integrated into ongoing teacher development programs.

For future researchers, there is an urgent need to expand DDR studies to the elementary school and college levels, as well as to subjects that have not been extensively studied, such as statistics, combinatorics, and calculus. More importantly, future research needs to adopt stronger methodological designs—such as quasi-experimental or longitudinal mixed-methods designs—to generate more valid and generalizable evidence of DDR's effectiveness. The integration of DDR with digital learning technologies is also a promising area of research.

For curriculum developers and education policymakers, the findings of this study can serve as a foundation for promoting the integration of the DDR approach into the development of national learning materials and competency standards for mathematics teachers. Thus, efforts to improve the quality of mathematics education can be carried out in a more systematic and evidence-based manner.

REFERENCES

Abdullah, A., Juandi, D., & Sugandi, A. I. (2022). Didactical design for overcoming misconceptions in mathematics learning. Jurnal Didaktik Matematika, 9(1), 45–58. https://doi.org/10.24815/jdm.v9i1.25780

Angraini, L. M. (2021). Didactical design of mathematical reasoning in basic mathematical concepts courses. JNPM (National Journal of Mathematics Education), 5(1), 1–12. https://doi.org/10.33603/jnpm.v5i1.3943

Brousseau, G. (1997). Theory of didactic situations in mathematics. Kluwer Academic Publishers.

Dela, R., Mohamad, G. J., & Erik, S. (2025). From learning obstacles to instructional design: Bridging theory and practice in algebra education through Didactical Design Research. Indonesian Journal of Educational Innovation and Research, 4(2). https://doi.org/10.31949/ijeir.v4i2.15308

Eka, F., Sugiatno, S., Munaldus, M., Hamdani, H., & Sayu, S. (2024). Didactical design with problem posing to overcome epistemological obstacles in problem solving. Journal of Mathematics Didactics, 10(2). https://doi.org/10.24815/jdm.v10i2.33086

Herman, T., & Prabawanto, S. (2021). Students' epistemological obstacles in learning mathematical concepts: A qualitative analysis. Infinity Journal, 10(1), 65–80. https://doi.org/10.22460/infinity.v10i1.p65-80

Juhaevah, F., Upu, H., Bernard, B., & Talib, A. (2025). Trends and recommended practices in didactic design for mathematics learning: A systematic literature review. Journal of Scientific Research, Education, and Technology, 4(4). https://doi.org/10.58526/jsret.v4i4.954

Munawwaroh, A. G., Pramudya, I., & Nurhasanah, F. (2025). Epistemological obstacles in the process of learning mathematical abstraction: A systematic literature review. KnE Social Sciences. https://doi.org/10.18502/kss.v10i11.18749

Nurhasanah, F., Pramudya, I., & Riyadi. (2021). Analysis of epistemological obstacles in mathematical abstraction learning. Journal of Physics: Conference Series, 1776(1), 012041. https://doi.org/10.1088/1742-6596/1776/1/012041

OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing. https://doi.org/10.1787/53f23881-en

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Pauji, I., Kusharyadi, R., & Khotimi, A. Z. (2023). Bibliometric analysis: Research trends on epistemological obstacles from 2000 to 2022. JPMI (Journal of Innovative Mathematics Learning), 6(3). https://doi.org/10.22460/jpmi.v6i3.17583

Pauji, I., Suryadi, D., Setambah, M. A. B. B., & Hendriyanto, A. (2023). Learning obstacles in the introduction to numbers: A critical study within the framework of didactic design research. Indonesian Journal of Science and Mathematics Education, 6(3), 430–451. https://doi.org/10.24042/ijsme.v6i3.19792

Pramudya, I., Mardiyana, M., & Saputro, D. R. S. (2023). Didactical design research for enhancing conceptual understanding in secondary mathematics education. Beta: Journal of Mathematics Education, 16(2), 119–136. https://doi.org/10.20414/betajtm.v16i2.428

Riastuti, A., Juandi, D., & Suryadi, D. (2023). Trends in research findings on learning obstacles in mathematics education over the past ten years. Jurnal Math-UMB.EDU, 10(3). https://doi.org/10.36085/mathumbedu.v10i3.5261

Suryadi, D. (2010). Metapedadidactics and Didactical Design Research (DDR): A Synthesis of Findings Based on Lesson Study. Bandung: FPMIPA UPI.