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Crafting math minds: A bibliometric odyssey into innovative didactical designs for learning (2006-2023)

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Abstract

The importance of Didactical Design in mathematics education must be addressed. Didactical Design is essential in mathematics education because it can optimize learning. Efforts to design learning experiences that combine didactic and design principles can lead students to acquire knowledge correctly and epistemically. This research aims to capture the landscape of previous research relevant to Didactical Design in Mathematics Education. This study constitutes a literature review research, wherein 56 publications were gathered from the Scopus database. These publications were subsequently subjected to bibliometric analysis with the assistance of the VOSviewer application. The analysis results show a rapid increase in publications since 2019, primarily focusing on didactic design, barriers to student learning, mathematics education, and retrospective analysis. The study also identified the emergence of new themes in Didactical Design research, such as the study of specific mathematical competencies and the integration of technology in design, e-learning, augmented reality, and STEM. Several implications are presented as helpful information for scientists and stakeholders.

Keywords: bibliometrics; didactical design; mathematics education

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Introduction

Mathematics education is a crucial field of study in the formation of people's knowledge and skills in this era of globalization (Rosas et al., 2023). In this context, Didactical Design plays an important role as the main basis for designing effective and efficient mathematics learning (Ruthven et al., 2009; Supriadi, 2019). Didactical Design combines two key concepts, namely 'didactic c ' which refers to the principles of diffusion and acquisition of knowledge from various educational environmental contexts , as well as 'design' which is related to the process of planning and structuring learning (Kotsyuba et al., 2022; Teichmann et al., 2023). In general, the principle of Didactical Design refers to a systematic approach in designing mathematics learning that can facilitate in-depth understanding of concepts and the application of mathematical skills in various contexts of daily life (Fuadiah et al., 2019; Marfuah et al., 2022).

The importance of Didactical Design in the context of mathematics education cannot be ignored (Jannah et al., 2017; Wahyuningrum et al., 2017). The existence of Didactical Design is very important in mathematics education because it can optimize the learning process (Nur'aeni et al., 2019; Prabowo et al., 2022). By designing learning that is based on strong didactic principles and supported by appropriate learning design, teachers can create a learning environment that motivates, challenges and inspires students (Brandenburger & Teichmann, 2022). The importance of Didactical Design is also reflected in its ability to identify students' learning needs and design learning strategies that suit their level of understanding (Prediger, 2019). By understanding student characteristics, learning contexts, and objectives of mathematics education, Didactical Design is able to guide teachers in designing teaching strategies that suit students' needs and level of understanding (García-Perales & Palomares-Ruiz, 2020). This is important because mathematics education is not just a transfer of knowledge, but also the development of logical thinking, creativity and problem solving abilities (Wahyuningrum et al., 2019). The importance of Didactical Design lies not only in the effectiveness of learning, but also in forming students' critical and analytical thinking patterns (Olsson & Granberg, 2022; Supriadi, 2022). By designing learning experiences that combine didactic and design principles, students can understand mathematical concepts more deeply and are able to relate them to real-world situations (Maulana et al., 2022; Nyman & Kilhamn, 2015).

However, why should we consider Didactical Design in the context of mathematics education? Mathematics has a very important role in everyday life, forming analytical thinking patterns, and developing problem solving skills (Schreiberova & Moravkova, 2023). Mathematics is a universal language that opens the door to opportunities in many fields, including science, technology, engineering, and economics. Therefore, it is important for us to design mathematics lessons that not only educate students about mathematical concepts and skills, but also stimulate their interest and interest in this subject.

Mathematics education today faces complex challenges, especially with the development of technology and the ever-changing demands of the job market. Therefore, developing relevant and effective Didactical Design is becoming increasingly important. Didactical Design in the context of mathematics education is not just a teaching method, but also a holistic approach that considers student diversity, understands the characteristics of mathematics learning, and explores students' potential in developing their understanding of mathematics (Burgos & Chaverri Hernández, 2022). In particular, Didactical Design can help teachers in choosing learning methods, compiling teaching materials, and evaluating student understanding. By referring to didactic principles and instructional design, teachers can create learning environments that inspire and support students' mathematical development (Salinas et al., 2013; Solares & Block, 2021).

To overcome students' learning difficulties, several previous studies have in-depth examined the Didactical Design Research (DDR) approach in mathematics learning. Research conducted by Pauji et al., (2023) regarding learning obstacles in geometry material, by highlighting ontogenic, epistemological and didactic obstacles, provides valuable insights and a basis for developing more effective didactic designs. Likewise, Angraini, (2021) on basic mathematical concepts using the triangulation method to create didactic designs that successfully reduce students' learning difficulties, confirms that DDR can be an effective tool for increasing students' understanding. In this context, Suryadi, (2013) also made a significant contribution with his approach which included in-depth analysis of mathematics teachers' thinking processes, resulting in an Empirical Didactical Design that continues to be refined. These studies together create an important foundation for the development of research approaches able to lead students to acquire mathematical knowledge correctly and epistemically.

Research gaps in the three studies can be identified through bibliometric analysis by paying attention to several aspects. First, although research conducted by Pauji et al., (2023); Suryadi, (2013) covers various aspects of Didactical Design Research (DDR) in the context of mathematics learning, there is potential to explore the variety of approaches and methodologies used in DDR research at a more detailed level. Bibliometric analysis can provide a more in-depth picture of research trends, topic focus, and contributions of individual researchers, allowing the identification of areas that have not been well explored. In addition, through bibliometric analysis, specific research gaps can be identified, such as educational levels that are less researched, sub-materials in geometry that still receive minimal attention, or methodologies that are rarely used. With a deep understanding of these gaps, bibliometric research can fill these gaps, providing new contributions to Didactical Design Research in mathematics education.

The urgency of this research was carried out because of the importance of understanding the relationship between Didactical Design and mathematics education. Bibliometric analysis is a scientific approach that allows researchers to understand the development of literature and research trends related to Didactical Design in mathematics education (Wang et al., 2021; Zyoud et al., 2015). By exploring existing literature, this research will provide in-depth insight into the contribution of Didactical Design in improving the quality of mathematics learning and identify knowledge gaps that need to be filled through further research. Combining the Didactical Design concept with mathematics education presents great potential in producing a more relevant and contextual learning approach, which will ultimately help produce a generation that is skilled in mathematics and ready to face the challenges of an increasingly complex and dynamic modern world (Rohaeti et al., 2019). Therefore, this research has a high urgency to bring new insights and enrich existing approaches to mathematics education, preparing students for the future.

The aim of this research is to conduct a bibliometric analysis of literature related to Didactical Design in mathematics education. By conducting this analysis, researchers hope to make a significant contribution to the development of mathematics education by summarizing existing research trends, identifying knowledge gaps, and formulating future research directions that will help improve the quality of mathematics learning at various levels of education. Thus, it is hoped that this research can provide a solid foundation for the development of Didactical Design in the context of mathematics education, support the achievement of better mathematics learning, and prepare the younger generation to face increasingly complex and dynamic future challenges.

Methods

In the pursuit of information related to "Didactical Design in mathematics education," researchers opted to utilize the Scopus database due to its extensive interdisciplinary coverage. In this study, researchers used the PRISMA method design with the initial phase involving identification, followed by screening, eligibility and finally the inclusion step as shown in Figure 1 (Moher et al., 2009). The first step, identifying relevant publications using search strings and removing identical or duplicate publications. The topic and scope is "Didactical Design". This means that only publications with those words are selected for the advanced search process. There were 330 publications that were identified and no duplicates were obtained. The second step, screening is carried out in selecting publications in subject areas and languages. The subject area chosen is mathematics because mathematics is part of this research and the language that must suit the researchers' needs is English because it is the international language most widely used in communication in scientific work. The only type of document required in this research is articles. After the screening process was carried out, 272 publications were removed or removed from the data because they did not meet the criteria, leaving only 58 publications remaining.

In the third phase, a total of 58 publications will undergo assessment for suitability. Researchers will manually examine titles and abstracts to determine which publications align with the inclusion criteria, specifically focusing on research involving Didactical Design in mathematics education. Only publications meeting these criteria will be included in the subsequent analysis of research discussions. At the conclusion of this stage, two publications were excluded due to their lack of relevance to Didactical Design in mathematics education. As a result, 56 publications remained. The objective of this research is to explore trends and landscapes in research related to Didactical Design in mathematics education. Therefore, all 56 publications were included to ensure the objectivity of the interpretation results. This data was collected on October 13, 2023, during the inclusion stage.

Descriptive analysis was conducted on trends in publications related to Didactical Design in mathematics education using data from the Scopus database and bibliometrics. The graph illustrates the number of publications and a linear trend line for each year over the past decade.

Citation trends for these publications were examined annually, and the average publication citations were calculated using Microsoft Excel. To determine the h-index and g-index, Harzing's Publish or Perish software was employed. This categorization reflects the journals with publications ranked above a certain threshold. The distribution of publications by country was visualized using Microsoft Excel, creating a world map showcasing the varying concentrations of publications across different countries. Additionally, VOSviewer software was utilized to generate network visualizations that highlight relationships between countries. To analyze the research focus, co-occurrence of keywords related to Didactical Design in mathematics education was examined using Scopus database data, which underwent preprocessing. The shared keywords were visualized using software to determine the prominent research themes.

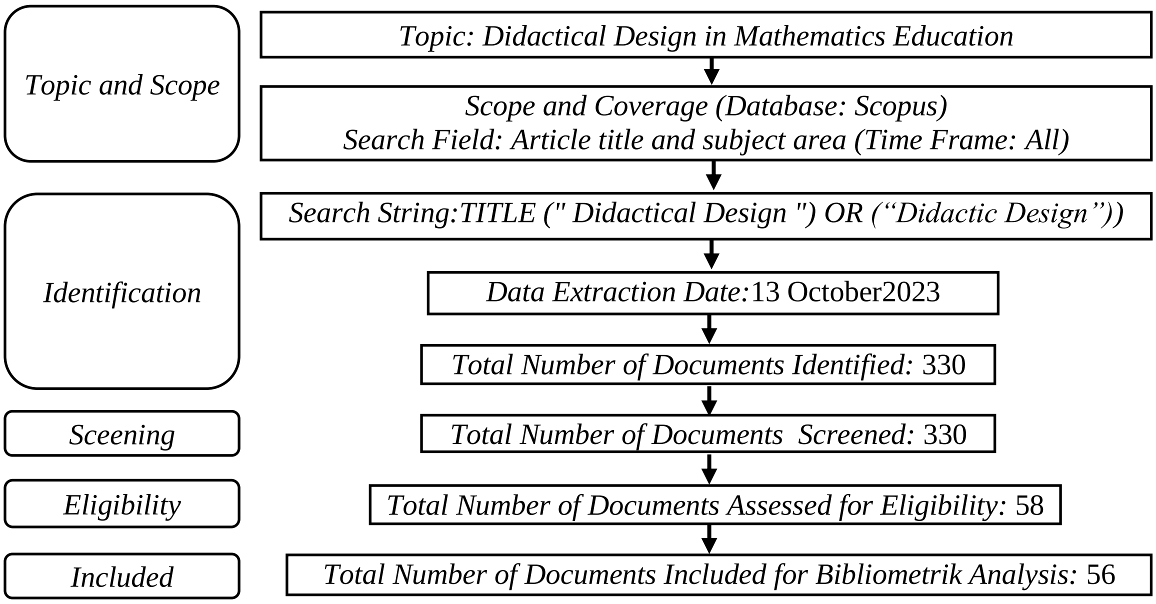


Figure 1. Data collection

Results

In this segment, the findings of the study are articulated in a comprehensive and lucid manner. The presentation of research results can be organized either by the progress at each stage of the research or by addressing specific problem formulations. It is imperative that the outcomes of the study are clearly substantiated with empirical evidence.

Publication trends and growth in research interest

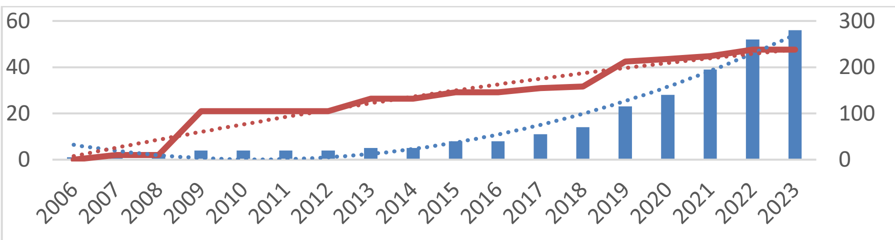


Figure 2. Cumulative number of publications and citations

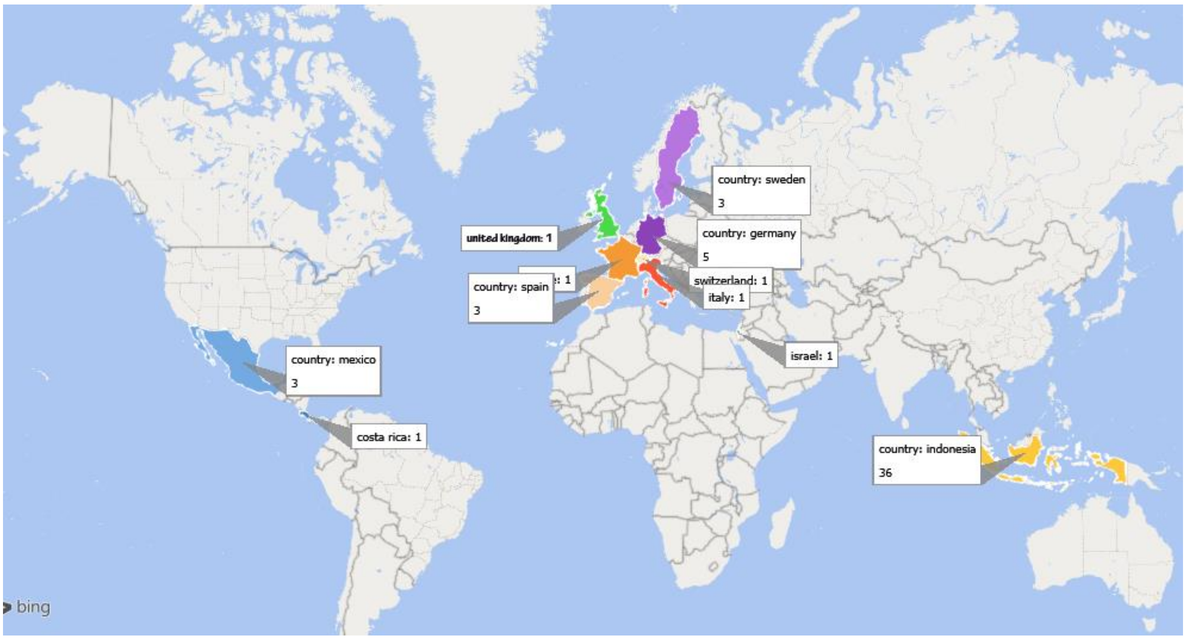
Over the past 18 years, there have been 56 research articles on Didactical Design in mathematics education published in the Scopus database (Figure 2). The initial publication surfaced in 2006 by Zaretsky. Notably, the surge in interest for Didactical Design research in mathematics education began in 2019, where the number of publications tripled from 2018. Subsequently, annual publications experienced a continuous upward trend, leading to a significant overall increase in cumulative publications. Optimistically, the hope is for this annual publication growth to persist. Unfortunately, a majority of these articles are not freely accessible, requiring users to pay for information access. It is observed that articles published in open-access journals tend to receive more citations. Interestingly, in 2006, 2007, and 2023, no articles were published as open access.

The Didactical Design research field is expansive, with active contributions from researchers worldwide. An analysis of study fields in the Scopus database reveals that Social Sciences, Computer Science, and Mathematics are the primary focuses in Didactical Design studies. This is supported by the total publications classified in the following subject areas: Social Sciences (170 articles), Computer Science (125 articles), and Mathematics (58 articles). This shows that Didactical Design in the field of mathematics has significant influence and relevance. With 58 articles recorded in the Scopus database, Didactical Design research in mathematics provides a valuable contribution to the understanding of mathematics teaching and learning methods at various levels of education. Researchers within and outside the field of mathematics can utilize these findings to improve their teaching approaches and address challenges that may arise in mathematics learning. Overall, Didactical Design research in mathematics, Computer Science, and Social Sciences provides a solid foundation for improving teaching approaches in a variety of disciplines. Collaboration between researchers, educators and technology experts in this field can strengthen the knowledge base of Didactical Design and enrich existing learning methods. By continuing to explore knowledge and share findings, we can create a more effective, inclusive and innovative learning environment for future generations.

Leading countries, top institutions, and international collaboration

Figure 3 shows the 11 most productive countries contributing to the growth in research activities related to Didactical Design in mathematics education worldwide. About 60% of global publications are contributed by Indonesia. This shows that Indonesia is a key country in the progress of Didactical Design research in mathematics education. Indonesia is the top country with 36 publications. Germany is ranked as the second most productive country. Apart from that, there are also four universities that are included in the list of the top 1 2 00 best universities based on the World University Rankings 2022, Indonesian Education University (Top 1200), Tecnológico de Monterrey (Top 200), Universitat de Barcelona (Top 200) and Umea University (Top 200). Top 400). This shows that the field of Didactical Design in mathematics education has received attention from top universities in the world.

Country collaboration is shown in Figure 4. The closer two countries are located to each other, the stronger the link and the thicker the line the stronger the link between the two countries. The highest number of publications by continent came from the Asian continent (37), followed by Europe (15) and America (5). This means that there are two other continents (Australia and Africa) that have not published articles related to this field in the Scopus database. The results of the joint writing show that 4 countries have collaborated regarding the publication of Didactical Design in mathematics education . Some possible factors contributing to the dynamics of international collaboration can be attributed to the diversity of research partners, a high percentage of foreign graduate/graduate students, and strong research funding.



Rank	Country	TPc	SCp	TC	The Most Article Produtive Academic Institution	Tpi
1	Indonesia	36	64%	72	Universitas Pendidikan Indonesia	25
2	Germany	5	9%	20	Technische Universität Dortmund	3
3	Mexico	4	7%	39	Tecnológico de Monterrey	3
4	Spain	3	5%	14	Universitat de Barcelona	2
5	Sweden	3	5%	4	Umea University	2

Figure 3. 11 countries and the top 5 most productive academic institutions

Figure 4. Screenshot of the bibliometric map based on co-authorship

Table 1. List of the 4 most prolific authors

Author	Scopus Author ID	Year of 1st publication*	TP	H-index	TC	Country
Suryadi, Didi	57190302080	2017_b	9	3	29	Indonesia
Nur'Aeni, E	57202359681	2018_a	5	1	2	Indonesia
Rijal Wahid	57202360810	2018_b	4	1	2	Indonesia
Supriadi, S	57211095138	2019_a	4	2	17	Indonesia

$_a$: First author; $_b$:Co-author.

Leading authors

Table 1 lists the 4 most productive authors related to Didactical Design research in the field of mathematics. These 4 authors are affiliated and come from the same country, namely, the Indonesian University of Education in Indonesia. The first productive writer is Didi Suryadi from Indonesia who has published 9 articles related to Didactical Design in Mathematics Education. Currently Didi Suryadi is known for DDR (Didactical Design Research). This means that Didi Suryadi has become a pioneer in Didactical Design research in mathematics education, establishing himself as one of the leading experts in this field. Through DDR (Didactical Design Research), he has produced nine in-depth and influential scientific articles, making a significant contribution to our understanding of how to design effective and meaningful mathematics learning. Apart from that, Didi Suryadi's success also reflects the excellence of the Indonesian Education University in supporting research in the field of Didactical Design. This institution has become a place for the development of leading experts and researchers, who together have made important contributions to the world of mathematics education. Their success also illustrates Indonesia's dedication to improving the quality of education, not only at the national level, but also globally.

The achievements of Didi Suryadi and his colleagues create a solid foundation for further developments in mathematics education, paving the way for innovation, discovery, and a deeper understanding of effective learning. With this research, it is hoped that mathematics education throughout the world will continue to develop, creating a generation that is skilled and understands mathematics, which in turn will have a positive impact on society and science as a whole.

Leading keywords

There are 293 keywords (100%) used in at least 1 document, 58 keywords (20%) used in at least 2 documents, and 31 keywords (10%) used in at least 3 documents. Next, the researchers determined a threshold, namely only keywords used in at least 2 documents (58 keywords) that would be analyzed further. After that, the 58 keywords will be filtered, where keywords that are almost the same are combined and keywords that are not suitable will be discarded. From this filtering process, 37 keywords were obtained.

Terminology and concepts

From the results of the network visualization display in Figure 5, it shows that "student" is the keyword that appears most frequently in Didactical Design research in Mathematics Education with 22 occurrences and 137 links to other keywords. Next in second place is the keyword "didactic design" (18 occurrences, 77 links), in third place is "mathematics education" with 15 occurrences and 64 links to other keywords. Apart from that, the use of general terms such as 'learning obstacles' (14 occurrences, 92 links). In the context of Didactical Design, "student" is a very important key element. With 22 occurrences and 137 links to other keywords, the emphasis on students shows that Didactical Design in mathematics education focuses on students' learning experiences. This indicates that researchers really understand the need to understand students' perspectives in the mathematics learning process. By understanding students' learning needs, abilities and barriers, the development of didactic design can be more effective and relevant. Therefore, research in the field of Didactical Design tends to focus on how to design learning experiences that accommodate the diversity of students, understand their thinking patterns, and overcome the obstacles they may face. By prioritizing students in mathematics learning design, Didactical Design seeks to create a learning environment that supports, inspires, and motivates students to achieve a better understanding in mathematics.

Meanwhile, the keyword "learning obstacles" is a key concept that refers to the obstacles or difficulties faced by students when they learn mathematics. This concept includes various types of obstacles that can hinder students' understanding of subject matter, ranging from difficulty understanding basic concepts to difficulty connecting more complex concepts. In Didactical Design research, identifying and understanding learning obstacles is very important because it helps teachers and mathematics learning designers to develop effective teaching strategies. The importance of understanding learning obstacles in Didactical Design is also related to efforts to improve the quality of mathematics education. By identifying the obstacles that students often face, educators can design more relevant and engaging learning experiences. Additionally, by understanding learning obstacles, teachers can provide additional support to students who are experiencing difficulties, enabling them to overcome these obstacles and achieve better understanding.

Research that focuses on learning obstacles can also make an important contribution to the development of a more inclusive mathematics curriculum. By understanding the barriers that different types of students may face, curriculum designers can create learning materials that are more accessible to all students, including those with different levels of understanding or learning styles. Thus, Didactical Design research that highlights learning obstacles not only provides in-depth insight into the challenges faced in mathematics learning, but also helps create an inclusive learning environment and supports the development of all students.

According to Wahyuningrum et al., (2019) there are three types of learning barriers, namely ontogenic barriers, didactic barriers, and epistemological barriers. Ontogenic barriers occur due to a mismatch between students' understanding and the material being taught, while didactic barriers arise due to inadequate teaching practices. Epistemological barriers occur because of students' limitations in the context of mathematics learning. Furthermore, Wahyuningrum et al.,

(2019) also said that to overcome these learning obstacles, it is necessary to take steps such as understanding students' basic knowledge, using effective teaching methods, and providing a variety of learning contexts so that students can develop new understandings about the topic of ratios and proportion.

In research on learning negative numbers in seventh grade in Indonesia conducted by (Fuadiah et al., 2019), several learning barriers were identified. These obstacles include epistemological aspects, where teachers explain the concept of negative numbers incorrectly, causing students to misunderstand. In addition, there are conceptual barriers where students have difficulty understanding the concept of negative numbers and related mathematical operations, such as adding and subtracting negative numbers. Barriers to symbolic representation also emerge, where students have difficulty understanding and using mathematical symbols related to negative numbers, such as the minus sign (-). Furthermore, Fuadiah et al., (2019) said that to overcome these obstacles, research recommends several steps, including designing learning programs that pay attention to identified learning barriers, using active and interactive learning approaches, providing real and relevant examples. , provide continuous practice opportunities, and provide constructive feedback to students. It is hoped that these steps can increase students' understanding of the concept of negative numbers more effectively.

From the two studies mentioned, it can be concluded that learning barriers in mathematics learning involve ontogenic, didactic and epistemological aspects. Ontogenic barriers are related to the mismatch between students' understanding and subject matter, while didactic barriers arise due to inadequate teaching methods. Epistemological barriers occur because of students' limitations in the context of mathematics learning. To overcome these barriers, an effective approach involves a deep understanding of students' basic knowledge, the use of active and interactive teaching methods, and the provision of a variety of learning contexts. Other recommendations include providing real, relevant examples, providing ongoing practice opportunities, and providing constructive feedback to students. By implementing these steps, it is hoped that students' understanding of mathematical concepts can be improved effectively, overcoming the learning barriers identified in the research.

The color of the keyword circle in Figure 5 shows the cluster or research focus. There are 4 clusters containing several keywords. More complete information regarding research clusters can be seen in table 2. The largest circle of keywords in each cluster is the research focus. The size of the circle shows how frequently the keyword is used. The larger the circle size, the more often the keyword is used. In the red clusters or the largest, the research focus is didactic design and students . This means that didactic design and students are the first research focus related to didactical design research in mathematics education. Didactic design and students in mathematics education refers to understanding students' level of knowledge, abilities and potential, as well as paying attention to their learning styles. By understanding both didactic design and students as individuals, mathematics learning approaches can be adjusted effectively to facilitate optimal understanding and development of mathematics skills in each student. Therefore, didactical design research in mathematics education often emphasizes good alignment between good learning design and the needs and characteristics of students as learners.

The second research focus is mathematics education and teaching (table 2). This means that it provides a comprehensive view of how didactical design can be designed to overcome students' learning barriers in the context of mathematics learning, thereby creating an effective and deep learning experience for students. The third research focus is learning obstacles, teaching materials and learning trajectories. We already know the importance of understanding learning obstacles, then in the context of didactical design, teaching materials and learning trajectories are key factors in overcoming these learning obstacles. In the context of didactical design, designing teaching materials that consider students' learning barriers is very important. Teaching materials should be structured in such a way that they can help students overcome the ontogenic, didactic, and epistemological obstacles they may encounter. This involves selecting effective teaching methods, using clear visual representations, and gradually introducing mathematical concepts to overcome epistemological barriers. Meanwhile, understanding learning trajectories or understanding the development of students' understanding over time is key in designing an adaptive curriculum. By understanding learning trajectories, educators can plan gradual and in-depth learning, allowing students to build their understanding from the most basic to more complex levels. By aligning learning obstacles, teaching materials, and learning trajectories, a comprehensive and integrated learning approach can be created, helping students overcome learning obstacles and achieve a deep understanding in mathematics.

The fourth research focus is retrospective analysis, and geometry, in the context of didactical design in mathematics learning, these 2 keywords are two keywords that describe analytical approaches to mathematics learning from two different perspectives. Retrospective analysis refers to reviewing teaching methods that have been applied in the past. By analyzing previous mathematics learning, researchers can identify patterns, successes, and possible difficulties, and gain valuable insights for improving future learning methods. On the other hand, geometry refers to the branch of mathematics that is concerned with the shape, size and properties of space. In the context of didactical design, the study of geometry opens up opportunities to design creative and interactive learning approaches, involving geometric concepts to build students' understanding of the relationship between mathematical objects and the real world. By combining retrospective analysis and geometry in mathematics learning, this research aims to develop relevant and effective didactic strategies, enabling students to understand geometric concepts in depth through a tested and structured learning approach.

Didactical design research in mathematics education emphasizes the importance of alignment between good learning design and student needs. The first focus on didactic design and students illustrates the need to understand students' level of knowledge, abilities and potential as well as their learning styles to develop appropriate learning approaches. The second research on mathematics education and teaching provides a comprehensive view of learning design to overcome barriers to student learning, creating deep learning experiences. The third focus on learning obstacles, teaching materials, and learning trajectories highlights the importance of designing teaching materials that consider student learning obstacles and understand the development of student understanding over time. Meanwhile, the fourth focus on retrospective analysis and geometry offers an analytical approach to teaching methods that have been applied in the past and combines geometric concepts to build student understanding. Overall, the integration of these four research foci allows the development of relevant and effective didactic strategies, creating a structured, comprehensive, and in-depth approach to mathematics learning for students.

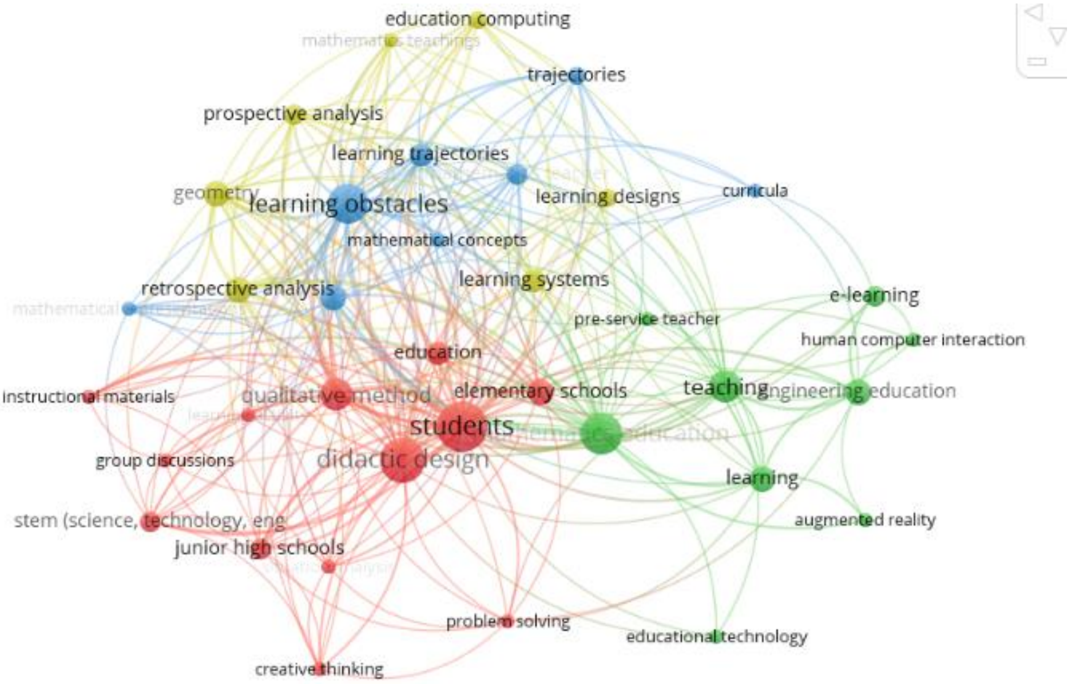


Figure 5. Network visualization

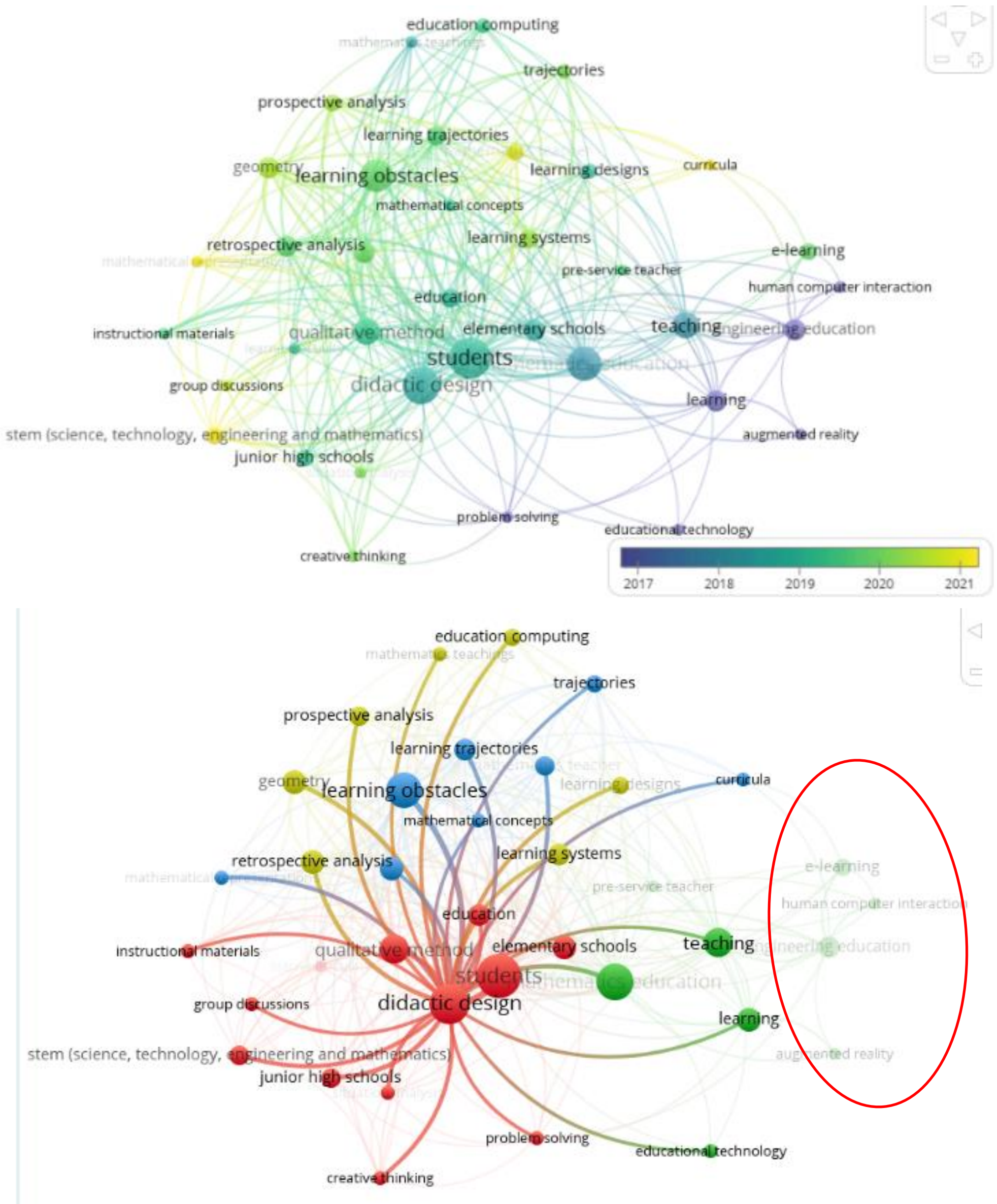
Table 2. Six Clusters related to Didactical Design

Cluster	Item	Research focus
1 (Red)	13	didactic design and students
2 (green)	9	mathematics education, and teaching
3 (blue)	8	learning obstacles , teaching materials and learning trajectories
4 (yellow)	7	retrospective analysis , and geometry

Latest keywords and relationships between keywords

Figure 6 (a) illustrates the latest advancements and research trends in Didactical Design in Mathematics Education, represented by new keywords highlighted in varying shades of yellow circles. This shift in research interest indicates ongoing efforts to deepen our understanding of the significance of Didactical Design in mathematics education. Exploring new keywords such as "mathematic representations," "STEM," "curriculum," and "geometry" offers potential for uncovering insights into the influence of factors like "student" and "learning obstacles" on mathematics learning and achievement. While the emergence of these new keywords suggests progress, it's crucial to acknowledge that the field may still be in a developmental stage. Further comprehensive research is needed to gain a more detailed understanding of Didactical Design in Mathematics Education. Recognizing the limitations and weaknesses of prior studies remains pertinent in shaping future research endeavors.

In Figure 6 (b), the primary theme, Didactical Design, is not yet interconnected with other keywords like "pre-service teacher," "e-learning," "learning activity," and "augmented reality." This signifies unexplored aspects within didactical design research in mathematics education. Investigating the relationship between didactical design, pre-service teachers, e-learning, learning activities, and augmented reality presents an opportunity for in-depth exploration. Understanding how prospective teachers in training can apply didactical design principles through e-learning, diverse learning activities, and augmented reality technology is an area ripe for research. Such exploration may reveal insights into how technology integration enhances didactical design effectiveness, optimizes learning activities, and supports the development of students' mathematical skills. Examining these relationships can significantly contribute to the innovation and student-centered orientation of mathematics education.



b

Figure 6. Novelty of research

Discussion

This research provides significant implications for the mathematics learning process and the Didactical Design research field as a whole. First, the research results highlight the importance of in-depth understanding of students, both in terms of knowledge, abilities, potential, and learning obstacles they may face. By understanding students holistically, the Didactical Design approach can be tailored to individual student needs, creating an inclusive learning environment and supporting the development of all students. Second, this research shows that identifying and understanding learning obstacles is very important in designing effective learning strategies. Overcoming learning barriers involves developing interactive teaching methods, using relevant learning materials, and providing constructive feedback to students. By paying attention to students' learning barriers, educators can develop learning approaches that support students in overcoming difficulties and achieving better understanding.

Third, the implications of this research also involve the application of technology, such as e-learning and augmented reality, in mathematics learning. Technology integration in Didactical Design can increase learning interactivity, diversify learning activities, and provide a more interesting and relevant learning experience for students. Therefore, this research provides a new view on how technology can be used effectively in the context of Didactical Design. However, there are several limitations in this research. First, although this research covers a period of the last 18 years, it cannot yet cover the latest developments in the field of Didactical Design due to time cuts in knowledge. Second, although there is an emphasis on geographical diversity in research, the main focus is still centered on certain countries such as Indonesia and Germany, so there may be expanded involvement of other countries to gain a more holistic understanding of the implementation of Didactical Design throughout the world. Third, although technology is highlighted as an important factor in this research, there is no in-depth analysis of the challenges and limitations of using technology in mathematics learning with the Didactical Design approach.

The results of this research are in line with the results of Supriyadi et al., (2023) research which recognizes several research limitations, such as limitations in covering the latest developments in the field of DDR and the main focus on certain countries such as Indonesia and Germany. As well as the importance of identifying and understanding students' learning barriers in designing effective learning strategies, including developing interactive teaching methods and providing constructive feedback to students. Supriyadi et al., (2023) also said that it is important to apply technology in didactic design content. According to Hudson, (2011) DDR considers how technology can be used to increase the interactivity and effectiveness of learning. Technology can be used to facilitate more interactive and inclusive learning, such as the use of e-learning, simulations and educational games. In addition, according to Hudson, (2011) technology can also be used to facilitate faster and more constructive feedback between teachers and students, as well as between students and each other.

Further research could explore this aspect further to provide a more comprehensive view of the use of technology in Didactical Design. In order to optimize mathematics learning, educators and policymakers must consider the findings of this research. By applying the results of this research in learning practice, it is hoped that students' mathematics learning experiences can be improved, learning obstacles can be overcome, and student learning outcomes can be improved overall.

Conclusion

Over the last 18 years, 56 research articles related to Didactical Design in mathematics education have been published, showing increasing interest since 2019. These publications mainly revolve around Social Sciences, Computer Science and Mathematics issues, this shows significant influence in the field of mathematics. The country of Indonesia is a major contributor to Didactical Design research, with the Indonesian University of Education standing out as a research center. Strong international collaboration is also evident, enriching cross-cultural understanding of Didactical Design. The research focus involves Didactic Design, students, mathematics education, learning obstacles, teaching materials, and learning trajectories. Learning obstacles include ontogenic, didactic, and epistemological barriers, highlighting the need for tailored teaching strategies to overcome students' learning difficulties. The use of new keywords such as mathematical representations, STEM, curriculum, and geometry shows the latest developments in research. The integration of Didactical Design with these aspects offers opportunities for innovative research and deepens understanding of mathematics learning.

This research highlights the importance of a deep understanding of students and their learning barriers. Identification of learning barriers and integration with technology (such as e-learning and augmented reality) can form an inclusive and innovative learning approach. Understanding the relationship of geometry to the real world can also enhance students' learning experiences. Didactical Design research in mathematics education continues to grow, deepening understanding of student needs and effective learning strategies. Integration with technology and a deep understanding of learning obstacles opens the door to innovation and better mathematics learning in the future.

Conflicts of Interest

The author declares that there is no conflict of interest regarding to this article.

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Author Contributions

Ilham Muhammad: Conceptualization, Writing - original draft, editing, and visualization; **Dadan Dasari and Dadang Juandi**: Writing - review & editing, formal analysis, and translating.

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