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Discovery Learning Research in Mathematics Learning (1968-2023): A Bibliometric Review

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Abstract

The aim of this research is to identify research developments related to Discovery Learning in mathematics learning. This research uses a bibliometric analysis method by collecting data from the Scopus database. The data is then saved in two formats, namely CSV and RIS. Data in CSV format was analyzed using VOSviewer, while data in RIS format was analyzed using Harzing's Publish or Perish software. This research refers to 72 research sources regarding discovery learning in mathematics learning from 1968 to 2023. The research results show that the number of publications related to discovery learning in mathematics learning continues to increase every year. Publications in 2012 had more than 130 citations, this number exceeds publications in other years. The majority of these publications were found in Q2 category journals, with a total of 28 publications. The focus of this research covers three main areas: 1) learning outcomes, learning environments, and the role of universities; 2) technology and STEM (Science, Technology, Engineering, and Mathematics); 3) problems in teaching mathematics. New themes that emerge in research regarding discovery learning in mathematics learning include STEM, communication, self-confidence, learning activities, creativity, critical thinking, and efficacy. However, the term "Discovery Learning" is not yet directly connected to new concepts such as critical thinking and learning methods. This research provides in-depth insight into the development of Discovery Learning in the context of mathematics learning, as well as a better understanding of the dominant research focus and current trends in this field.

***Keywords**: bibliometric, discovery learning, mathematics learning.*

INTRODUCTION

Education is very important and can improve the quality of human resources (Marchy et al., 2022; Muhammad & Yolanda, 2022). Sudarsana et al., (2019); Widyanti et al., (2021) stated that education is a conscious effort to create a learning process that can develop students' self-potential and become human beings with noble character. In improving the quality of education in learning, educators can apply several learning

methods, one of which is by applying the Discovery Learning (Yadi & Nirwana, 2023). According to Honomichl & Chen (2012) Discovery Learning is an important but controversial topic in the fields of psychology, education, and cognitive science.

According to Bruner (1961) Discovery Learning is a process where students can understand meaning, concepts, and relationships through a process of intuition, until finally they can find a conclusion that is adapted to the cognitive development of students. Discovery Learning is a learning model that changes learning from teacher-centered learning to student-centered learning so that students learn actively by discovering themselves, investigating themselves and cultivating a scientific attitude (Inde et al., 2020; Tanjung et al., 2020). Meanwhile according to Ponidi et al., (2020); Pratiwi & Miriam, (2022); Suratno et al., (2019) Learning model with Discovery Learning is a constructivist learning model that combines the principles of learning by discovery and radical constructivism with the principles of constructivism learning design theory. Discovery Learning is also interpreted as a series of activities in learning that involve students' abilities to find systematically, critically and analyze so that they can formulate their own findings covering cognitive, affective and psychomotor aspects (Batubara, 2019; Syarif et al., 2020). So, Discovery Learning is a student-centered learning model that involves students' ability to discover a concept.

Through Discovery learning, students can also learn to think analytically and try to solve problems (Fahmi et al., 2019; Linggile & Payu, 2022; Marta et al., 2022). Meanwhile according to (Sunarsih et al., 2020) through learning Discovery Learning provides opportunities for students to discover a concept through examples found in everyday life. Discovery Learning is not only able to improve students' metacognitive abilities but also able to improve communication skills and student learning outcomes (Dewi et al., 2022). In addition, the use of discovery learning models also has an impact on developing students' creative thinking abilitiesa (Winita et al., 2020). Discovery learning method has six sequences namely stimulation, problem identification, data collection, data processing verification and generalization (Anggraini et al., 2018).

Mathematics is an important knowledge for students to acquire which is useful in solving problems in everyday life (Mayani et al., 2022). Discovery learning is appropriate to be applied to mathematics learning because it has a better influence on learning outcomes (Atiyah et al., 2020; Novantri et al., 2020). learning model with Discovery

learning for learning mathematics can improve students' learning achievement in mathematics (Ramdhani et al., 2017). Meanwhile according to Honomichl & Chen (2012) learning models with Discovery learning can improve problem solving skills.

Discovery learning research has developed very rapidly in the last decade, Discovery learning research has also produced many findings in various fields of study (Wicaksono et al., 2021). Discovery learning research in education has indeed increased in recent years, but not only in education in general, discovery learning research in mathematics learning has also increased in recent years (Pratiwi & Miriam, 2022). This means that an increase in research related to discovery learning in education is also followed by an increase in research on discovery learning in education, especially in the field of mathematics. For this reason, it is necessary to apply a statistical method to analyze the results of these studies in knowing the research focus and finding research novelty. Bibliometric analysis is a valuable method employed in the examination of research within specific studies.

Bibliometric analysis is a valuable method for examining publications. (Muhammad et al., 2023). Bibliometric is a statistical method that contains a variety of information about research in a particular study (Muhammad et al., 2022). In obtaining this information from publications related to discovery learning in mathematics education, a database is needed. The research used in this research is derived from the Scopus database.

Research related to this research is like research conducted by (Wicaksono et al., 2021) regarding bibliometric analysis related to research on Discovery learning in general in science education taken from Scopus database publications. The bibliometric analysis presented in this study provides relevant information about the main themes learned about discovery learning in science learning, which can be seen in the increase in creativity, learning outcomes, and student achievement in teaching and learning activities at school. However, other subjects also publish articles, such as Psychology, Business, Management and Accounting, Arts and Humanities, Medicine, and Mathematics. Therefore, this study suggests that further researchers discuss discovery learning in other fields of science such as mathematics.

The objective of this study is to investigate the research focus and novelty associated with discovery learning in the context of mathematics education. Researchers

utilized the Scopus database to analyze publications spanning from 1968 to 2023. The study addresses the following research questions:

1. Publication and Citation Trends: What are the patterns in publications and citations concerning discovery learning? How are these trends related to the concept of discovery learning in mathematics education?
2. Journal Ranking Distribution: How are publications related to discovery learning in mathematics education distributed across different journal rankings? What does this distribution reveal about the significance of these publications in the academic community?
3. Country-wise Publication and Collaboration: How are publications related to discovery learning in mathematics education distributed among different countries? What are the collaborative relationships between countries in this research area?
4. Novelties and Research Focus: What are the innovative approaches and specific areas of focus in research related to discovery learning in mathematics education? What new contributions or perspectives have emerged in this field?

METHODS

This research employed a bibliometric analysis approach to examine publications related to Discovery learning in mathematics education, sourced from the Scopus database spanning from 1968 to 2023. The data collection process followed the steps of identification, screening, eligibility, and inclusion (Moher et al., 2009).

The identification phase involved entering specific keywords related to the research theme, namely "discovery learning" and "education," into the Scopus database. This yielded 823 publications meeting the specified criteria. Subsequently, a check for duplicate data was conducted, and as there were no duplicates found, all 823 publications proceeded to the next stage. During the screening phase, publications were scrutinized to ensure they were in the form of articles and were written in English. This process led to the exclusion of 82 articles that did not meet these criteria. Consequently, 741 publications that satisfied the requirements progressed to the eligibility stage for further analysis.

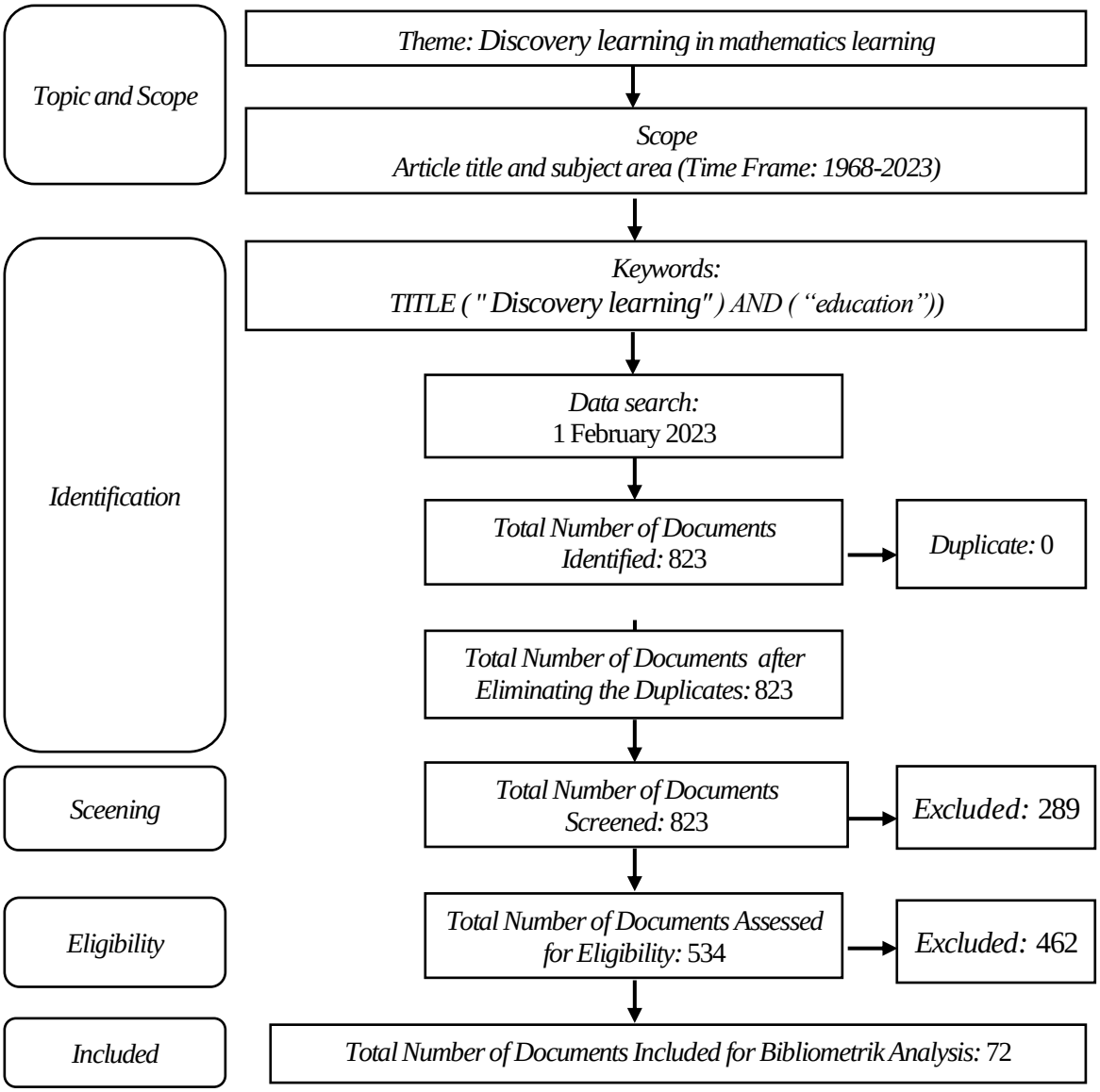

Figure 1. data collection process

The eligibility process involves evaluating the feasibility of 741 documents from the previous stage. During this phase, the titles and abstracts of these documents will be reviewed to determine if they contain the specific terms "discovery learning" and "mathematics learning." After conducting the eligibility assessment, 72 publications that meet the criteria were identified and can proceed to the inclusion stage.

Data analysis method

Data obtained from the Scopus database are processed and saved in two different formats: CSV and RIS. The CSV data is inputted and analyzed using VOSviewer, while the RIS data is entered into Harzing's Publish or Perish Software. The analysis focuses on the publication trends and citations of research related to discovery learning in

mathematics education, considering the year of publication. Additionally, the distribution of journals is examined based on their quartile values, and the countries of origin of the authors are analyzed, highlighting the relationships between countries. This analysis is conducted to identify novel research areas and themes, utilizing the VOSviewer application. Microsoft Excel software is utilized to visualize the distribution of countries on a world map and to display journal ranking distribution. Harzing's Publish or Perish software is employed to calculate metrics such as h-index and g-index, providing insights into citations and other related data.

RESULTS AND DISCUSSION

Publication trends and citation trends

The trend of publications related to discovery learning research and in mathematics learning from 1968 to 2023 continues to increase every year, this can be seen from the trend line shown in Figure 2 below.

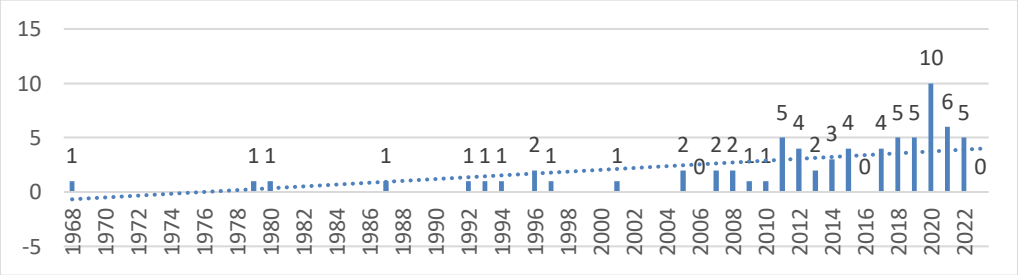

Figure 2. Publication Trends

The data presented in Figure 2 clearly indicates that 2020 was the peak year for publications in this specific field. In 2020, ten articles were published, marking a significant increase compared to the previous years. The most substantial surge occurred between 2019 and 2020, with the number of publications doubling during this period. Publications associated with the domain under consideration were traced back to 1968, where only one document was published. The trends in publications related to the exploration of discovery learning in mathematics are detailed in Table 1.

Table 1. Quotation Per Year

Year	TP	NCP	TC	C/P	C/CP	h	g
2023	-	-	-	-	-	-	-
2022	5	1	1	0,2	1	1	1
2021	6	6	16	2,67	2,67	3	3
2020	10	9	38	3,8	4,2	4	5
2019	5	5	37	7,4	7,4	4	5
2018	5	5	65	13	13	4	5
2017	4	2	24	6	12	2	2

Year	TP	NCP	TC	C/P	C/CP	h	g
2016	-	-	-	-	-	-	-
2015	4	4	40	10	10	3	4
2014	3	3	60	20	20	3	3
2013	2	1	11	5,5	11	1	2
2012	4	4	139	34,75	34,75	4	4
2011	5	4	37	7,4	9,25	4	5
2010	1	1	2	2	2	1	1
2009	1	1	4	4	4	1	1
2008	2	1	11	5,5	11	1	2
2007	2	2	127	63,5	63,5	2	2
2006	-	-	-	-	-	-	-
2005	2	2	112	56	56	2	2
2002-2004	-	-	-	-	-	-	-
2001	1	-	-	-	-	-	-
1998-2000	-	-	-	-	-	-	-
1997	1	1	9	9	9	1	1
1996	2	2	51	25,5	25,5	2	2
1995	-	-	-	-	-	-	-
1994	1	1	4	4	4	1	1
1993	1	1	14	14	14	1	1
1992	1	1	1	1	1	1	1
1988-1991	-	-	-	-	-	-	-
1987	1	-	-	-	-	-	-
1981-1986	-	-	-	-	-	-	-
1980	1	1	5	5	5	1	1
1979	1	1	16	16	16	1	1
1969-1978	-	-	-	-	-	-	-
1968	1	1	19	19	19	1	1

Table 1 illustrates the citation trends based on NCP (Normalized Citation Per Paper) values. Notably, 2020 recorded the highest NCP value of 9, succeeded by 2021 with an NCP of 6. However, when considering total citations (TC), 2012 stands out with 139 citations, making it the most influential year in this field. The significance of 2012 is underscored by its substantial citation count. Additionally, in 2007, the C/P (Citations per Paper) and C/CP (Citations per Citable Paper) values were the highest, primarily due to a large number of citations relative to the limited publications that year. Moreover, examining the h-index and g-index values reveals peaks in 2011, 2018, 2019, and 2020, emphasizing the impact of publications during these years.

Journal ranking distribution

When evaluating journal rankings, researchers commonly utilize quartile values from platforms such as Scopus or Scimago. After sorting journals according to these quartile values, researchers determine the count of publications in each quartile (Q1 to Q4) using a specific method.

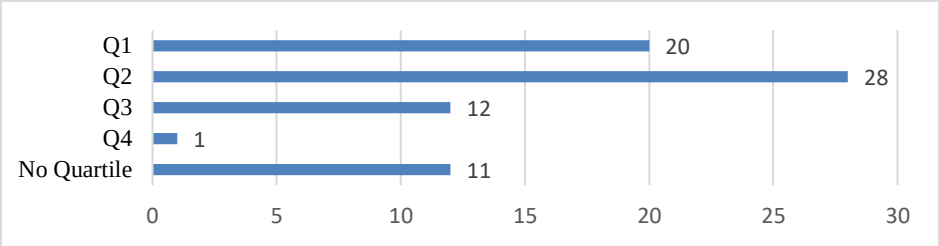

Figure 3. Distribution of Journal Ratings

The image illustrates a significant focus on discovery learning in mathematics within Q2 journals, with a total of 28 publications. In contrast, Q4 journals show the fewest publications, while 11 publications are featured in journals without assigned quartile values. The second-highest number of publications, 20 in total, is found in Q1 journals. Consequently, when Q1 and Q2 publications are combined, they account for over 65% of the total publications.

Distribution Mapping of Publications and Relations Between Countries

The researcher has compiled publications on discovery learning in mathematics education spanning from 1968 to 2023. These publications originate from 28 different countries. To represent this diversity, the researcher presents the distribution of countries as follows.

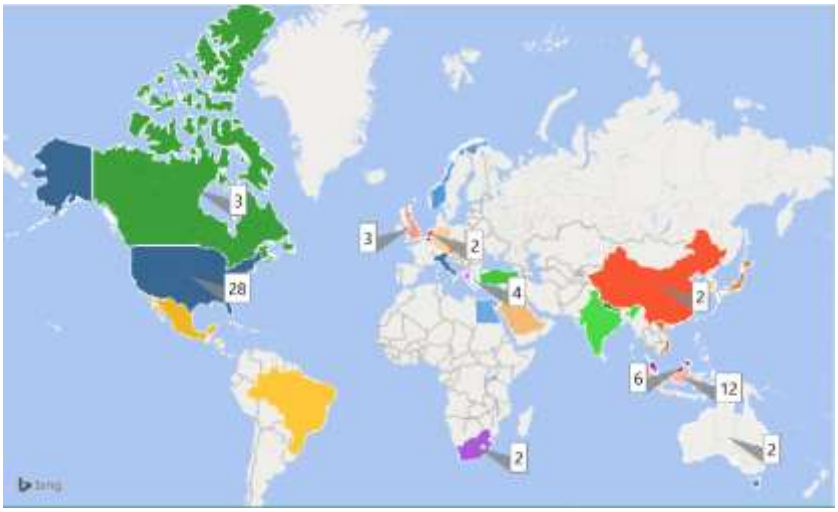

Figure 4. Geographic Distribution

Based on Figure 4, it is evident that the United States has produced the highest number of publications, with 28 documents focused on discovery learning in mathematics education. In comparison, Indonesia is in the second position with 12 publications. Examining the data by continent, publications have been contributed by all continents.

Notably, the American continent leads with 32 publications, constituting approximately 45% of the total documents related to discovery learning in mathematics education.

Figure 5. Pattern of Cooperation

In Figure 5 above, the connections between countries in research on discovery learning in mathematics education are depicted. It is evident that the United States has numerous connections with other countries, precisely 7 connections. This indicates that the United States not only leads in the number of publications but also demonstrates a high level of collaboration compared to other nations.

Novelty and Research Focus

Research on discovery learning in mathematics education from 1968 to 2023 has been categorized into three distinct clusters using the VOSviewer application. These clusters highlight the focal points of research in this field over the specified period.

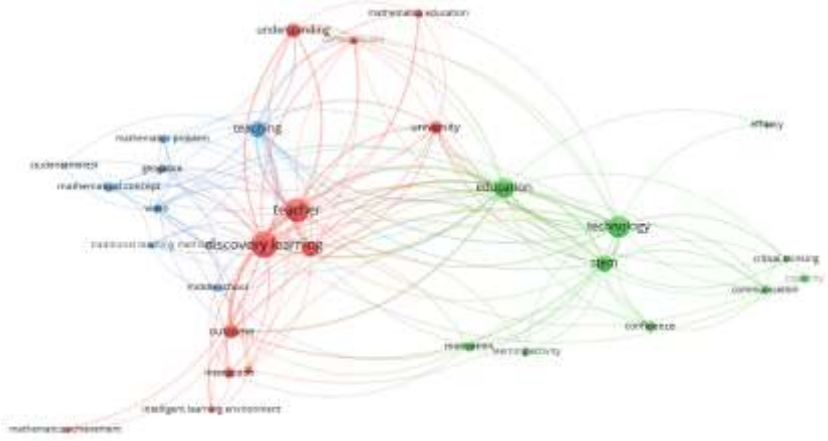

Figure 6. Network Visualization

In Figure 6, there are a total of 30 items categorized into three different colors in the VosViewer application. These colors represent the divisions in research focus related to discovery learning in mathematics education spanning from 1968 to 2023. The first focus area is denoted by red circles encompassing 12 items. Among these, the keywords with the largest circle diameters are discovery learning, outcomes, environment, and university, indicating that outcomes, environment, and university-related aspects are the primary focus of this area. The second research focus is represented by green circles, comprising 10 items. Within this category, technology and STEM stand out with larger

circles, signifying their significance as the primary subjects of the second research focus. The most recent area of research emphasis is indicated by blue circles, consisting of 8 items. Among these, the keywords teaching and mathematics problem have the largest circles, highlighting that teaching methods and mathematics problem-solving have become the central focus of the latest research in this field..

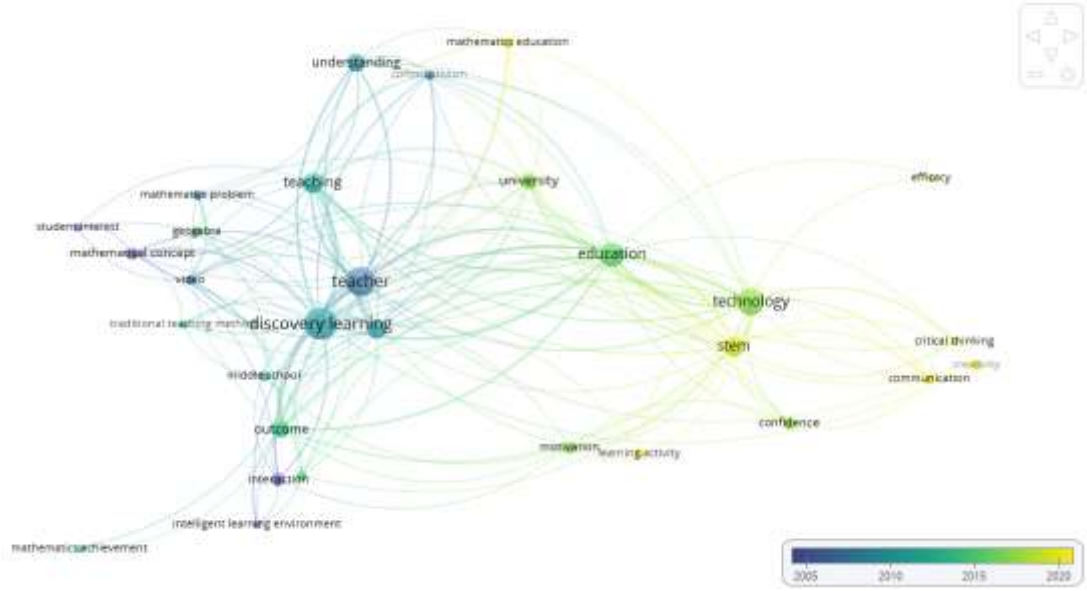

Figure 7. Overlay Visualization

In Figure 7, the color distinction represents the publication year of the keywords used. Blue keywords signify older themes, while yellow ones indicate recent themes in discovery learning research related to mathematics education. The new themes identified in this study encompass STEM, communication, confidence, learning activities, creativity, critical thinking, and efficacy. The novelty of discovery learning research in mathematics education is determined by examining the connections between keywords. Researchers analyze the focal points of their studies and identify new themes to gauge the novelty of their research. For instance, the primary focus on discovery learning in the initial research is not directly linked to emerging themes like critical thinking and specific learning activities. Similarly, technology-related keywords in the second research do not directly correlate with keywords in the third research focus, such as mathematics problems. Additionally, in the first research focus, the presence of the keyword "university" is not directly associated with creativity. This absence indicates a lack of research exploring the connection between discovery learning in mathematics education at the university level and creativity.

Discussion

What are the publication trends and citation trends related to Discovery learning research in mathematics learning?

The number of publications related to discovery learning research in mathematics education showed a significant increase from 2017 to 2020, spanning the period from 1968 to 2023. This is in accordance with what was conveyed by (Pratiwi & Miriam, 2022; Wicaksono et al., 2021) that Research on discovery learning, particularly in the field of mathematics, is experiencing rapid growth.

The citation patterns in the field of discovery learning research in mathematics education from 1968 to 2023 can be analyzed through various data points. Among these, the year 2012 stands out with a remarkable achievement in terms of citations. Specifically, publications from this year received the highest recognition, garnering a total of 139 citations. These articles, which achieved significant impact, exemplify the influence and relevance of discovery learning research within the realm of mathematics education, namely research conducted by (DeCaro & Johnson, 2012) with the title "Exploring mathematics problems preparing children to learn from instruction" suggests that various theories of learning and development emphasize children's ability to learn through exploration and self-discovery in their environment, without direct instructions from more knowledgeable individuals. In 2012, four publications garnered significant attention, making it the year with the highest number of citations.

Table 2. Articles published in 2012

Author (year)	*Sources*	*Citation*
(DeCaro)	Journal of Experimental Child Psychology	94
(Baroody et al)	Cognition and Instruction	30
(Batzel et al.)	American Journal of Physiology - Advances in Physiology Education	10
(Barrett & Long)	*Primus*	5

How is the distribution of journal ranking mapping from publications related to Discovery learning in mathematics learning?

The ranking of journals is established based on quartile values, spanning across 72 publications categorized from Q1 to those without assigned quartiles. Notably, a significant portion of publications concerning discovery learning in mathematics

education falls within Q2 journals, accounting for 28 publications. The table indicates the journal with the highest number of published articles in this field.

Table 3. The journal with the highest number of published articles

Journal	Number of Article
Journal of Chemical Education	17
International Journal of Scientific and Technology Research	5
PRIMUS	4
Universal Journal of Educational Research	2
Jurnal Pendidikan IPA Indonesia	2
Journal of Experimental Education	2
International Journal of Mathematical Education in Science and Technology	2

In the table above the journal "Journal of Chemical Education" has published articles related to discovery learning in mathematics learning from 1968 to 2023 with 17 publications. These journals can be used as publication destinations for researchers who take the theme of discovery in mathematics education.

How are publications related to discovery learning in mathematics education distributed among different countries? What are the collaborative relationships between countries in this research area?

The research literature on discovery learning in mathematics education from 1968 to 2023 is globally diverse, with contributions from every continent. The United States stands out as a key player in this field due to its significantly high number of publications in comparison to other countries. Additionally, the United States maintains strong interstate collaborations, enhancing its influence on the topic. This aligns with the findings of (Ali, 2018) that the United States of America is the most influential country in the field of mathematics which has been analyzed by bibliometric analysis. America also has cooperative relations with many other countries in the field of mathematics education (Julius, 2021).

What are novelty and discovery learning research focuses on learning mathematics?

Research on discovery learning in mathematics education from 1968 to 2023 has been divided into three main areas of focus, namely, 1) outcomes, environment and university; 2) technology and stem; 3) teaching and mathematics problems.

The first research focus is outcomes, environment and university. Several studies have linked learning outcomes with discovery learning in mathematics learning as done by (Kamaluddin & Widjajanti, 2019; Putriani & Rahayu, 2018) and associate with the university (Yuliana et al., 2017). According to (Kamaluddin & Widjajanti, 2019) the

impact of discovery learning on students' math proficiency encompasses cognitive, affective, and psychomotor domains. Each stage in discovery learning plays a vital role in enhancing mathematical understanding. Nevertheless, when aiming to enhance students' specific talents or skills, educators need to focus on particular steps that hold the most potential for improvement while still acknowledging the importance of other stages. Where according (Putriani & Rahayu, 2018) in the realm of education, there exists an approach closely tied to practical applications, specifically concerning the environment. The primary focus of this initial research revolves around discovery-based learning in the context of university-level mathematics education.

The second research focus is technology and stem. Research conducted by (Purwaningsih et al., 2020) who examined the effect of discovery learning associated with technology and stems, this research suggests that for further research it is necessary to pay attention to the level of flexibility of the technology used. The third research focus is teaching and mathematics problems. Research conducted by (Hulukati et al., 2018; Simamora et al., 2018) who has researched discovery learning and mathematics problems in mathematics learning, the results of this study indicate that there are differences in students' mathematical problem solving abilities caused by the learning model applied. The three aforementioned research focuses can serve as a valuable reference for future researchers exploring similar themes. Therefore, it is essential to conduct further research related to these specific areas of study.

New themes such as STEM, communication, confidence, learning activity, creativity, critical thinking and efficacy are keywords that have only been published in the last few years. Keyword discovery learning has not been directly connected with new themes such as critical thinking and learning activities. Furthermore, technology keywords are also not directly connected with keywords such as mathematics problems. The term "university" is not inherently linked to creativity, indicating a lack of research on the connection between discovery-based mathematics learning in universities and creativity. This novel perspective, especially when considering new thematic keywords or those not directly associated with existing ones, presents an opportunity for valuable future research.

CONCLUSION

From the results and discussion it can be concluded that publications related to discovery learning in mathematics learning continue to increase every year, especially from 2017 to 2020. Publications in 2012 have cited more than 130 citations, this number is more than any other year. Most of the research papers in this particular field were published in Q2 journals, totaling 28 publications. The United States of America stands out as the most influential country in this area of study. Researchers in this field are primarily focusing on three main themes: 1) outcomes, environment, and university; 2) technology and STEM (Science, Technology, Engineering, and Mathematics); 3) teaching and mathematics problems. In the realm of discovery learning research in mathematics education, emerging themes include STEM, communication, confidence, learning activities, creativity, critical thinking, and efficacy. Notably, the novelty of this research can be observed in the connections between keywords. However, it's interesting to note that the term "discovery learning" is not directly associated with newer themes like critical thinking and specific learning activities**.** Future researchers can take advantage of the research focus to determine the theme to be taken, then it is recommended for further research to make use of the novelty that has been discussed in this study. In searching for databases, further researchers can use databases other than Scopus, such as Google Scholar and others. The data obtained was taken from the Scopus database on January 10, 2023, for this reason, research results or publications after that date are not counted in this study, and there may be slight differences.

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