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Mathematical Communication Skills and Mathematical Curiosity Students with intellectual disabilities: Bibliometric analysis

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a b s t r a c t

This research aims to conduct a bibliometric analysis of the literature on mathematical communication abilities in children with intellectual disabilities. The primary focus of this research is to develop an overview of recent developments in the field and identify dominant research trends and areas requiring more exploration. Bibliometric methods are used to collect and analyze data from primary literature sources in articles and journals indexed by Scopus from 1990 to 2024, which are related to mathematical communication skills in children with intellectual disabilities. This research will also pay attention to the methods or approaches generally used in this research and evaluate the impact of this literature on developing understanding and intervention in improving the mathematical communication skills of children with intellectual disabilities. The result of this research was that no research discussed the relationship between children's communication skills, mathematical curiosity, and intellectual disability.

K e y w o r d s :
Bibliometric Analysis, Intellectual Disability, Mathematical communication, Mathematical curiosity

INTRODUCTION

Mathematical ability is an essential ability that needs to be mastered by every human being. Mathematics is vital in solving life problems (Safitri et al., 2021). In an increasingly complex and connected modern context, mathematics is vital in developing critical thinking, analytical, and problem-solving skills essential in the face of today's global challenges. Mathematics is a computational tool and a universal language that allows different disciplines and sectors, such as science, technology, business, and finance, to interact and collaborate. Through mastery of mathematics, individuals can develop abstraction, logic, and modeling skills that allow them to break down complex situations into more manageable elements. Therefore, learning mathematics is not just an academic task but an essential investment in preparing future generations to face global challenges with better readiness.

Most students, including children with special needs, struggle to learn mathematics. The impact of difficulty learning mathematics on children with special needs can be seen in their difficulties in carrying out daily activities (Safitri et al., 2021). For example, difficulties in understanding the concepts of numbers and measurements can hinder their ability to manage money, calculate time, or plan activities. In addition, difficulties in spatial understanding and geometry can affect navigation and orientation skills, both in the physical environment and in maps. Unsolved math problems can also affect children's confidence and motivation, possibly leading to frustration and unwillingness to engage in learning or social activities. Therefore, understanding and overcoming the difficulties of learning mathematics in children with special needs is essential in ensuring they have full access to fun learning and experiences and can optimally develop their potential.

According to Lambert & Tan (2020), In 2013–2017, articles discussing difficulties learning mathematics in children with disabilities (dyscalculia, developmental dyscalculia, mathematical disabilities, mathematical learning disabilities, and at risk for mathematical disabilities), As many as 81% use quantitative methods. The quantitative approach provides objectively measurable data and figures, which allows for more in-depth statistical analysis of patterns of mathematical learning difficulties in children with disabilities. In quantitative research, researchers can identify trends, correlations, and significant differences in math learning difficulty levels between groups of children with and without disabilities and chart their progress over time.

Still, according to research by Lambert & Tan (2020), Only 13% used qualitative methods. This qualitative method allows researchers to understand the qualitative aspects of the mathematics learning difficulties experienced by children with these disabilities. In a qualitative approach, researchers can explore environmental factors, personal experiences, and individual perceptions that may not be directly measurable through a quantitative approach.

Based on Lambert & Tan's research (2020), in 2013–2017, only 7.35% of articles discussed mathematics learning difficulties in children with intellectual disabilities. This phenomenon highlights the importance of more in-depth research and a focus on groups of children with intellectual disabilities in the context of learning mathematics. Children with intellectual disabilities often face unique and complex challenges in understanding mathematical concepts, which can be affected by various factors, such as cognitive limitations and difficulty communicating. In fact, in learning mathematics in children with intellectual disabilities, communication skills are also as essential as reasoning (Boyd & Bargerhuff, 2009).

Mathematical communication is essential for developing and promoting students' mathematical skills with special educational needs (Choi et al., 2012; Genç & Özdemir, 2023; Handen, 2007). Mathematical communication is essential in understanding mathematical concepts in children with intellectual disabilities. Children with intellectual disabilities who can verbally or nonverbally communicate their thoughts about mathematics have a greater chance of developing a deeper understanding of mathematics.

On the other hand, understanding mathematics is also related to students' curiosity about mathematics (Lloyd et al., 2000; Reza Frastica Dewi & Zulmi Roestika Rini, 2023; Wilton, 2014). Understanding mathematics and curiosity are closely related to learning and developing mathematical knowledge. Intense curiosity is often the main driver in understanding complex mathematical concepts. When someone is curious to understand a mathematical topic, they tend to be more involved in exploring, asking questions, and looking for answers. This curiosity inspires individuals to solve problems and develop a deeper understanding of mathematics. In other words, curiosity is a trigger in a deep and continuous process of understanding mathematics, helping individuals overcome obstacles that may arise while learning mathematics.

Based on the relationship between communication and understanding and understanding with curiosity, a relationship between communication and curiosity can be drawn. Curiosity and communication are two elements that are intrinsically linked in the process of understanding and disseminating knowledge. Curiosity is the drive that drives individuals to seek answers to their questions, solve problems, or explore topics that interest them. On the other hand, communication is a means to achieve this goal by interacting with others, seeking information, and sharing knowledge. A study by Litman and Silvia (2006) in psychology underlines the importance of curiosity influencing an individual's motivation to seek new knowledge. They found that inquisitive people tended to seek information more actively and engage in knowledge-oriented communication.

Curiosity and communication are two aspects that complement and support each other in the process of knowledge exchange. Curiosity is a crucial communication driver, as we often seek answers to questions or a deeper understanding of a topic through interaction with others. Through questioning, discussion, and collaboration, communication allows us to gain greater insight, explore new ideas, and build shared knowledge. For example, research by Penney et al. (2015) on communication in an educational context suggests that intense curiosity can motivate students to participate in class discussions and seek further explanations actively, increasing their understanding of the subject matter.

Curiosity plays a central role in effective mathematics learning. Students with a high level of curiosity tend to be more eager to explore complex and challenging mathematical concepts. They actively seek answers to their questions, solve problems, and participate more actively in learning. In a study published in the journal "Educational Psychologist" by Day and Goldstone (2012), Researchers found that students with an intense curiosity in mathematics had better achievement in those subjects. Curiosity encourages students to go deeper in their understanding of mathematics and stimulates creativity in problem-solving, thus helping to create a more productive and fulfilling learning experience.

Curiosity has a significant role in the learning of children with intellectual disabilities. Children with intellectual disabilities often have the same natural curiosity as other children, although perhaps to different degrees. Curiosity can be the driving force in their learning process. Teachers and educators should encourage this curiosity by providing stimulating learning experiences through games, interactive activities, or engaging media. By acknowledging and harnessing the curiosity of children with intellectual disabilities, learning can become more meaningful and more effective.

Although it has a significant role, there is not much research on curiosity in children with intellectual disabilities. Research on curiosity has excellent relevance in various aspects of life, including education, science, and innovation. A deeper understanding of how curiosity arises, develops, and influences human behavior allows us to design environments that better support learning, identify factors that trigger discoveries, and drive innovation in various fields. This research also has the potential to broaden our understanding of how to overcome barriers that hinder curiosity and how to develop productive curiosity. One study that underscores the importance of research on curiosity is an article by Litman, Hutchins, and Russon (2005), which discusses the concepts and theories of curiosity and its impact in various disciplines.

LITERATURE REVIEW/ THEORETICAL FRAMEWORKS (IF APPLICABLE)

Intellectual disabilities (ID)

Intellectual disabilities (ID) encompass a range of conditions characterized by limitations in intellectual functioning and adaptive behavior, which can significantly impact an individual's ability to learn, communicate, and function daily. Research indicates that individuals with ID often face challenges in various domains, including academic skills, social interactions, and practical life skills Schnepel et al. (Schnepel et al., 2019). Understanding the multifaceted nature of intellectual disabilities is crucial for developing effective educational strategies and interventions that can enhance the quality of life for these individuals.

One of the critical areas affected by intellectual disabilities is mathematical learning. Students with ID frequently exhibit difficulties in acquiring mathematical concepts due to their cognitive limitations and challenges in problem-solving (Yıkmış & Terzioğlu, 2022; Yun et al., 2020a). For instance, studies have shown that traditional teaching methods may not be effective for these students, necessitating the adoption of specialized instructional techniques such as the TouchMath technique, which has been found to improve problem-solving skills among students with ID (Yıkmış & Terzioğlu, 2022). Additionally, the Virtual-Representational-Abstract (VRA) approach has shown promise in supporting mathematical understanding and skills in this population (E. C. Bouck et al., 2018a).

Mathematical Communication Skills Students with intellectual disabilities

Mathematical communication skills are essential for students with intellectual disabilities, enabling them to articulate their understanding of mathematical concepts and engage effectively in problem-solving activities. Research indicates that students with intellectual disabilities often struggle with both mathematical reasoning and communication, which can hinder their overall academic performance and limit their ability to participate in inclusive educational settings (E. C. Bouck et al., 2018b; Browder et al., 2010; Knight et al., 2019).

One significant factor contributing to the challenges faced by these students is their difficulty in understanding mathematical concepts and the language used to express them. For instance, students with learning disabilities may struggle to grasp academic calculations and theories, directly impacting their written mathematical communication skills (Aladwan, 2023; Yuniarti, 2023). This is further compounded by the need for explicit instruction in communication strategies, as many students with intellectual disabilities require structured approaches to develop their cognitive and self-regulation skills during mathematical problem-solving (Hord, 2022; Karabulut & Özmen, 2019).

Effective instructional strategies are crucial in enhancing mathematical communication skills among students with intellectual disabilities. The use of visual aids, graphic organizers, and technology-based learning environments has been shown to improve students' ability to communicate mathematical ideas (Baglama, 2019; Browder et al., 2010; Huscroft-Dâ€TMAngelo et al., 2014). Additionally, incorporating peer-mediated instruction and collaborative learning opportunities can foster an inclusive environment where students can practice and refine their mathematical communication skills (Franz et al., 2016; Jimenez et al., 2012a).

Mathematical Curiosity Students with intellectual disabilities

Mathematical curiosity is critical to effective learning, particularly for students with intellectual disabilities (ID). It fosters engagement, promotes problem-solving skills, and enhances overall academic performance. However, students with ID often face unique challenges that inhibit their curiosity and interest in mathematics. Research indicates that fostering mathematical curiosity in these students requires tailored instructional strategies that accommodate their specific learning needs and promote a positive attitude toward mathematics (Bowman et al., 2019; Yun et al., 2020b).

One practical approach to nurturing mathematical curiosity is integrating real-world contexts into mathematics instruction. This method, known as anchored instruction, situates learning in meaningful problems that resonate with students' experiences, motivating them to engage with mathematical concepts (Bowman et al., 2019). For instance, using practical applications of mathematics, such as budgeting or measuring in cooking, can help students with ID see the relevance of math in their daily lives, enhancing their curiosity and willingness to explore mathematical ideas (Yun et al., 2020b).

Moreover, fostering a supportive classroom environment that encourages exploration and inquiry is essential for developing mathematical curiosity among students with ID. Educators can create such an environment by promoting a growth mindset, where mistakes are viewed as learning opportunities rather than failures (Hasanah, 2023). Encouraging collaborative learning and peer interactions can also enhance curiosity, as students often learn from one another and feel more motivated to engage with mathematical tasks when they work together (Jimenez et al., 2012b).

METHODS

In this study, the method applied is bibliometric analysis, which utilizes bibliographic data to measure and analyze patterns, trends, and the impact of scientific literature in a scientific discipline or field of research. Bibliometric analysis is a literature review that needs to be carried out using a structured, explicit, and replicable approach (Fink, 2019; Garza-Reyes, 2015; Tranfield et al., 2003). Bibliometric reviews are generally applied in various disciplines and are focused on quantitative analysis of journal papers, books, and other types of written communication (Heersmink et al., 2011). In the context of this work, bibliometric analysis with the five-step approach introduced by Fahimnia et al. was used (2015). The approach involves the following steps: defining search keywords, executing the initial search, refining the search results, summarizing statistics from the initial data, and analyzing the data in detail in later subsections.

Define appropriate search terms

Keywords used in the search include "Intellectual disability," "mathematics," "Communication skills," and "curiosity."Search for these terms using the help of Publish or Perish 8, with the search source coming from Scopus. Data collection from Scopus is carried out in the hope of obtaining articles of good quality.

Initial search results

Table 1
Initial search results with searches based on selected keywords

Search keywords	Year of search	Number of articles
“Intellectual disability” and mathematics	1993-2023	198
“Intellectual disability,” mathematics, and “Communication”	2010-2023	15
“Intellectual disability,” mathematics, and “curiosity”	2020-2020	1
“Intellectual disability,” “mathematics,” “Communication,” “curiosity,”	all-time	0

From Table 1 above, until 2023, there are 214 articles related to "Intellectual disability," "mathematics," "Communication skills," and "curiosity." Most articles were obtained by typing the search for "Intellectual disability" and mathematics, resulting in 198 articles, with the oldest published in 1993. Searches with the keywords "Intellectual disability," "mathematics," "Communication," and "curiosity" have not found a single article.

There are not too many search results due to one of the uses other than Intellectual disability, such as mentally disabled, mental retardation, or mentally retarded. Searches conducted using the term Intellectual disability are based on the American Association on Intellectual and Developmental Disabilities, which considers the term Intellectual disability to have developed into the preferred term for most professionals (AAIDD, 2010). Therefore, using other terms on multiple articles to refer to the same term does not count as related articles.

Improved search results

From the initial search, results are filtered again by only taking sources that are journal articles and conference proceedings articles so that the following data is obtained.

Table 2
Filter results from the first search result

Search keywords	Year of search	Number of articles
"Intellectual disability" and mathematics	1993-2023	109
"Intellectual disability," mathematics, and "Communication"	2010-2023	8
"Intellectual disability," mathematics, and "curiosity"	2020-2020	1
"Intellectual disability," "mathematics," "Communication," "curiosity,"	all-time	0
Total	1993-2023	118

After filtering the previously obtained articles, 118 articles were obtained. The article is from journals and proceedings indexed by Scopus.

Preliminary data statistics

Based on Table 2 above, there are 118 articles from journals and proceedings published in the period 1993 – 2023 and have been published by 59 journals.

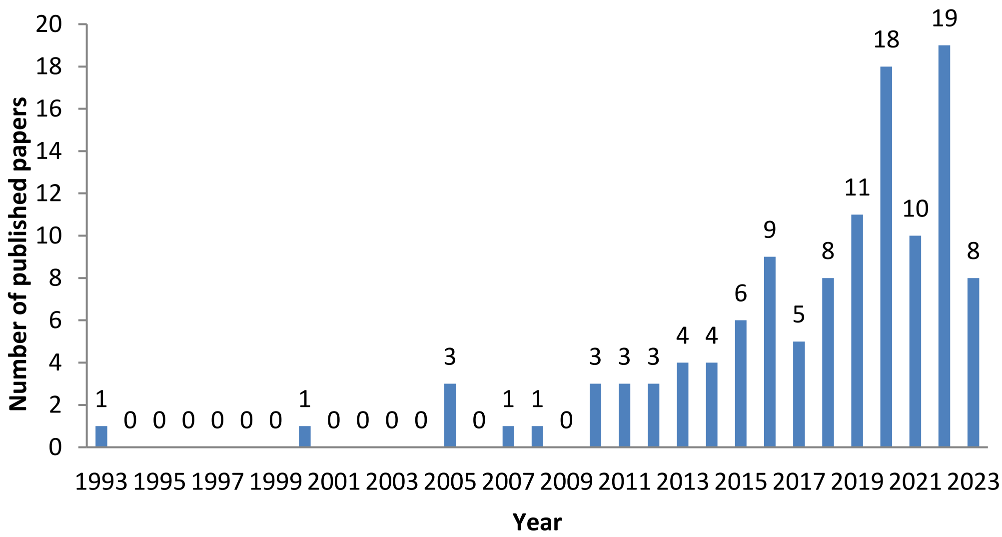


Figure 1
Publication trends with the theme of Mathematical Communication Skills and Curiosity of Students with Intellectual Disabilities

Based on Figure 1 above, the distribution of articles was published in 2020, 2021, and 2022. If analyzed further, that year was the period of the Covid-19 pandemic. From 1993 to 2000, only two articles were related to the terms used in the search. This happens because one of them still uses other terms besides Intellectual disability. Intellectual disability-indexed articles are articles written by (Center & Curry [20] entitled "A

Feasibility Study of a Full Integration Model Developed for a Group of Students Classified as Mildly Intellectually Disabled."

Data analysis

Once the data is successfully obtained, the next step is to perform an in-depth analysis using an effective tool like Vos Viewer. Vos Viewer is a software capable of turning complex data into informative visualizations. With the help of Vos Viewer, we can visualize relationships between different data elements, identifying patterns, trends, and findings that may be difficult to see just from raw data.

From the analysis results based on the article's title and abstract, 6 clusters were obtained: Cluster 1 (6 items) consists of academic mathematics instruction, developmental disability, mathematics instruction, programs, training, and strategy. Cluster 2 (5 items) comprises concept, intellectual disability, mathematics, numeracy, and teaching mathematics. Cluster 3 (3 items) consists of addition, fraction, and virtual manipulative. Cluster 4 (3 items) consists of effectiveness, learners, and problems. Cluster 5 (2 items) consists of individuals and practices. Cluster 6 (2 items) Consists of Communication and Memory.

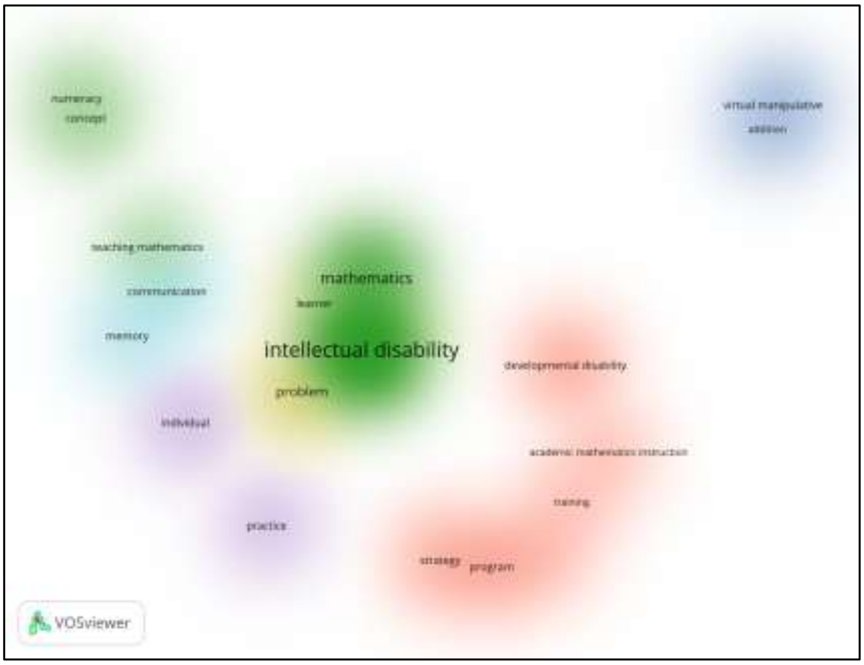


Figure 2
Clusters based on title and abstract

From clustered words, there is a relationship between words. For example, the word numeracy is connected to intellectual disability, strategy to training, and virtual manipulative is connected to strategy through intellectual disability. More details can be seen in Figure 3 below.

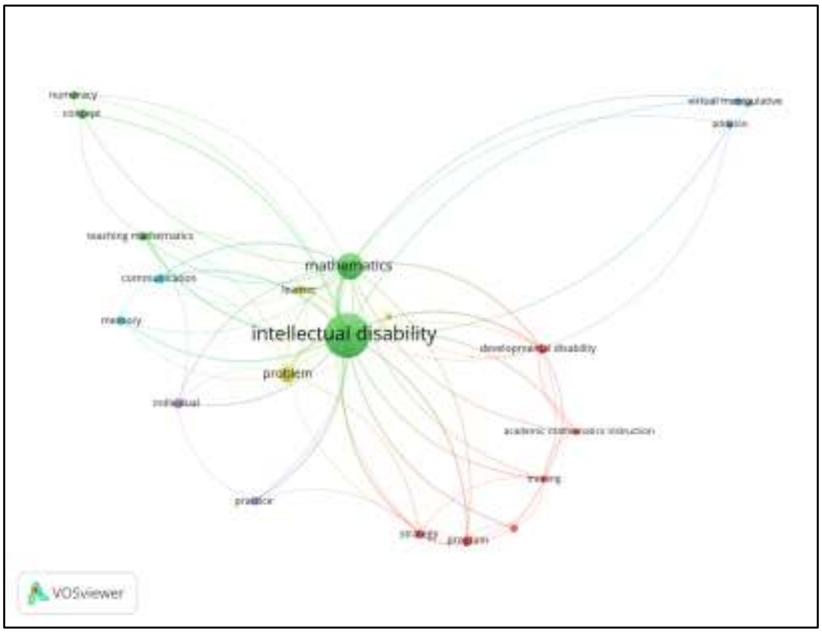


Figure 3
Network visualization of words that appear in titles and abstracts

Based on Figure 3 above, it can be seen that intellectual disability is a word that is widely found and characterized by a larger circle compared to other words found in articles and connected to other words such as mathematics (Brankaer et al., 2013; Gilley et al., 2021; Henry & Winfield, 2010; Pratama et al., 2019; J. Root et al., 2017; Stevens et al., 2015; Zilaey et al., 2017), and mathematical communication (E. C. Bouck et al., 2020; Jablan et al., 2010; Morsanyi et al., 2018; Muchyidin & Priatna, 2022; Saint-Georges, 2020; Sherawat & Punia, 2022; Windsor, 2023; Wright et al., 2020). From Figure 3, it can also be seen that the word curiosity does not appear, meaning that there has been no Scopus-indexed article that examines mathematical curiosity in children with intellectual disabilities, and this is the same as what is shown in Table 2 above.

In addition to clustering and the relationship between words, from the data obtained, author information with the number of articles produced.

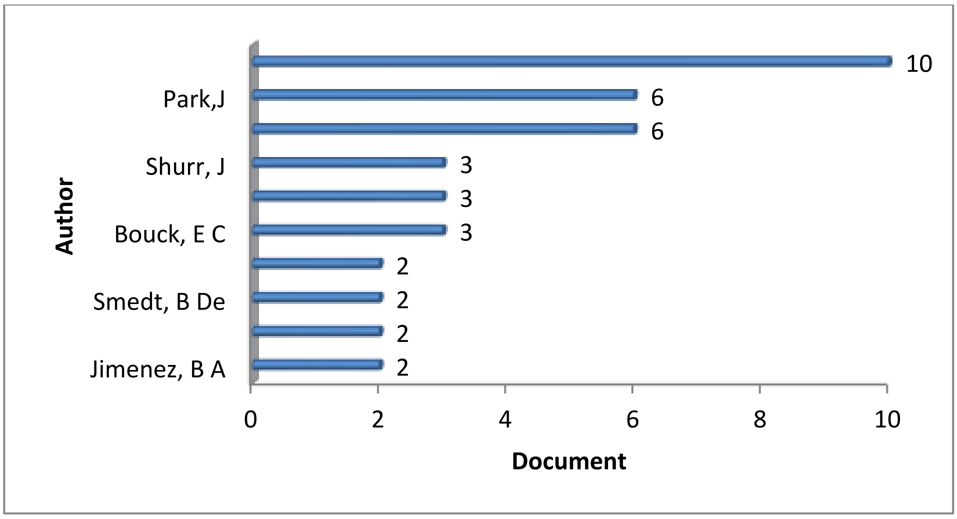


Figure 4
Top five authors with the most articles

RESULT AND DISCUSSION

Intellectual Disability

Mental retardation is a condition of withheld or incomplete development of the mind, which is mainly characterized by a decline in skills manifested during the period of development, which contributes to the overall level of intelligence, that is, cognitive, language, motor, and social abilities. Underdevelopment can occur with or without other mental or physical disorders. However, mentally retarded individuals can experience a variety of mental disorders, and the prevalence of other mental disorders is at least three to four times greater in this population than in the general population. In addition, mentally retarded individuals are at greater risk of physical/sexual exploitation and abuse. Adaptive behavior is always impaired, but in a protected social environment where support is available, this disorder may not be evident at all in subjects with mild mental retardation (World Health Organisation, 1996).

Historically, the term commonly used for intellectual disability was mental retardation. American Association on Disabilities and Developmental Disabilities (AAIDD), formerly named the American Association on Mental Retardation (AAMR), is among the more prominent professional organizations that support individuals with intellectual and developmental disabilities (Pavelko, 2017). Intellectual disabilities (AAIDD, 2010) has become the preferred term for most professionals. The definition of an influential ID is AAIDD [19]: Intellectual disability is characterized by significant limitations in intellectual functioning and adaptive behavior as expressed in conceptual, social, and practical adaptive skills. This defect originated before the age of 18. ID diagnosis requires three criteria to be met. The first criterion is significant limitations in intellectual functioning. Intelligence refers to general mental abilities and includes reasoning, planning, problem-solving, thinking abstractly, understanding complex ideas, learning quickly, and learning from experience (AAIDD, 2010).

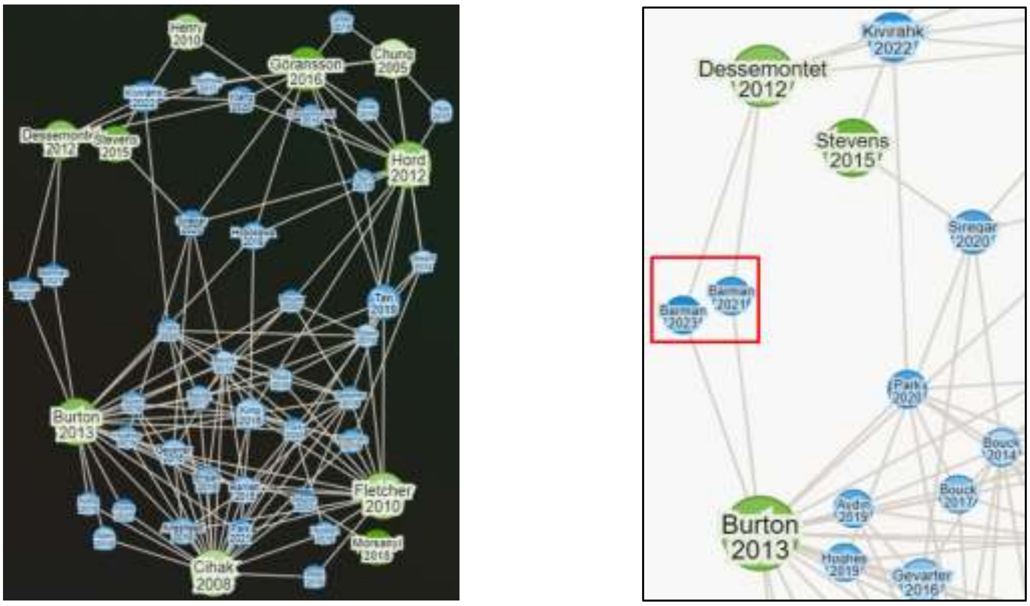
The change in terms from "mental retardation" to "intellectual disabilities" reflects the evolution of understanding and perception of individuals with intellectual challenges. This shift aims to remove stigma and embrace a more sensitive and inclusive approach. The term "mental retardation" has negative connotations and is often used pejoratively, leading to discrimination and stereotypes. By adopting the term "intellectual disabilities," society seeks to create a more welcoming and supportive environment for individuals with special needs, recognizing their right to be respected and treated fairly. These changes reflect a positive step towards inclusion and recognition that everyone has unique values and contributions to society, regardless of their intellectual abilities. In addition, using different terms also affects the search results of articles that use the term "intellectual disabilities" in this study.

As seen in Figure 1 and Table 3, the first article to use the term intellectual disability and indexed by Scopus was published in 1993. The article appears in the journal Disability, Development and Education, written by the Yola Center and Craig Curry (Center & Curry, 1993). In the study, the Yola Center and Craig Curry evaluated the feasibility of a full-time functional integration model by comparing the academic and social achievements of two groups of students with mild intellectual disabilities. Both groups were randomly allocated to general classes according to age or to separate special classes. During the experimental phase, one teacher remained in the unit while the other acted as a resource teacher for students with integrated disabilities and regular students who experienced low progress in the general classes where students with disabilities were allocated. In addition, in one regular classroom where the resource teacher established mastery/cooperative group learning procedures, regular students and students with disabilities experienced significant improvements in academic skills compared to parallel groups in traditionally organized classes.

Contribution of articles to research related to Intellectual Disability

Based on Table 4, the article with the most citations is "Effects of Inclusion on the Academic Achievement and Adaptive Behavior of Children with intellectual disabilities," written by R. Sermier Dessemontet, G. Bless, and D. Morin (2012). The article discusses the background and results of a study on the impact of inclusion on the development of children with intellectual disabilities (ID). Although many studies have explored inclusion outcomes for students with special needs, especially learning disorders, their effect on the development of children with ID is less revealed. The study compared an experimental group of 34 children with IDs fully included in general education classes with support and a control group of 34 comparable children in special schools. The progress achieved by both groups in academic achievement and adaptive behavior was compared over two years of schooling. The study concludes that inclusive education is a suitable educational option for primary students with ID who need intensive support in school, which is in line with the results of previous studies (Cole & Meyer, 1991; Hardiman et al., 2009; Saint-Laurent et al., 1993).

The interesting thing from Table 4 is that if the ten articles are mapped, then the articles (authors) are related. The relationship can be in the form of direct linkage. It can also be related because it is associated with the author or other articles, as can be seen in Figure 4 below:



a b

Figure 5
Linkage between articles

Based on Figure 4.a above, it is clear that each article from Table 4 (green color) is related to each other, either directly related or related because it is connected to other articles (blue color). From Figure 4.a above, ten articles in green can be separated because of the role of 37 other articles (blue). For example, consider Figure 4.b above; an article written by Dessemontet et al. (Dessemontet et al., 2012) and articles written by Burton et al. (Burton et al., 2013) are not directly linked but are linked by another article written by Barman and Jena (Barman & Jena, 2023b, 2023a). In addition to the linked articles listed in Table 4 (in green), it turns out that the articles listed in Table 4 (in green) also connect articles from two articles. For example, the article written by Stevens et al. (2015) became a link to articles written by Kivirähk and Kiive (Kivirähk & Kiive, 2022) and Siregar et al. (Siregar et al., 2020). This means that all the articles listed in Table 4 have a very large contribution to research related to Intellectual Disability.

Based on Figure 4.a, the network of relationships between authors in the article in Table 4 involving several authors, it appears that Emily C. Bouck contributed very large to the network. Emily C. Bouck contributed three articles central to the network (E. Bouck et al., 2017; E. C. Bouck et al., 2014; E. Bouck & Satsangi, 2020a). One of them is a central article (E. C. Bouck et al., 2014) and related to 11 articles as written by Siregar et al. (Siregar et al., 2020), Park et al. (Park et al., 2020), Bouck and Satsangi (E. Bouck & Satsangi, 2020b), Aydin and Tekin İftar (Aydin & Tekin İftar, 2020), Root (J. R. Root, 2016), Spooner, et al. (Spooner et al., 2019), King et al. (King et al., 2016), Gevarter et al. (Gevarter et al., 2016), Ehsan et al. (Ehsan et al., 2018), Barnett and Cleary (Barnett & Cleary, 2015), and Fletcher et al (Fletcher et al., 2010). The relationship between the articles written by Emily C. Bouck [54] and these articles can be seen in Figure 5 below.

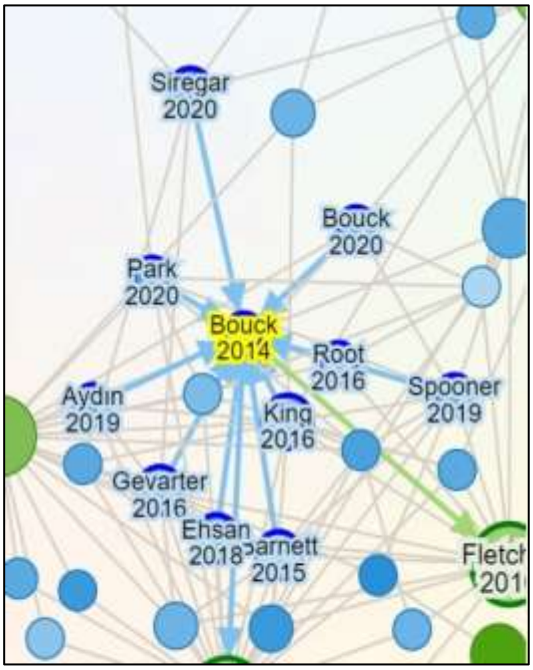


Figure 6
Bouck's article contributions

The word that appears most in the title and abstract

In addition to the relationship between words and the relationship between authors, this study also obtained the most common word findings found in abstracts and titles. The word that appears a lot can be said to be the keyword of the research discussed by the researchers.

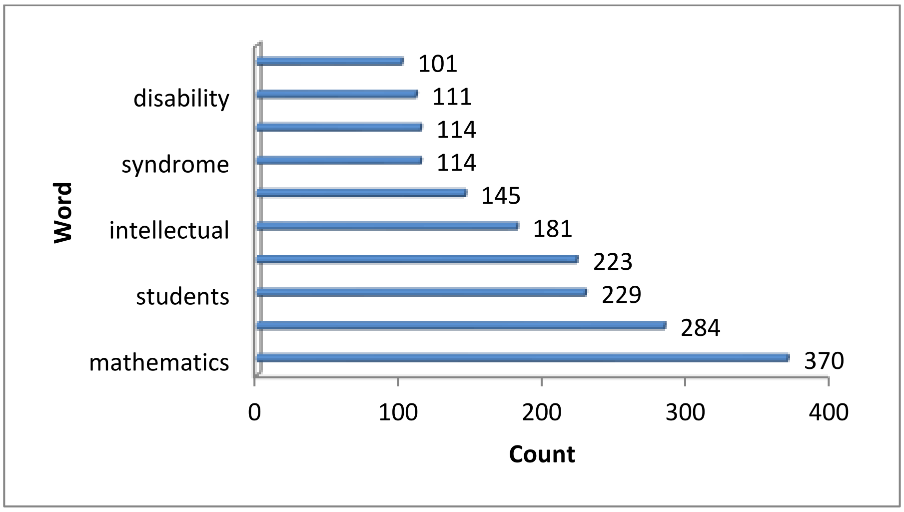


Figure 7
Top ten words that appear most on abstract and titles

In Figure 6 above, the word that appears most in the abstract and title is mathematics 370 times, followed by education 284. However, in Figure 3, the word intellectual disability has the largest circle compared to other words, followed by the word mathematics, which has a circle smaller than the word intellectual disability but larger than other words that appear. This seems to contradict Figure 6, which places mathematics as the most populous word. Nevertheless, if scrutinized, in Figure 6, the number of intellectual words appears 181 times, and the word disabilities appears 223 times. The total number of words for intellectual disability appears to be 404 times, in line with Figure 3 above.

CONCLUSION

Based on a bibliometric analysis of research on children with intellectual disability from Scopus-indexed articles in the period 1990 to 2023, the conclusion that can be drawn is that there are no articles that specifically discuss aspects of mathematical curiosity in children with intellectual disability. Although the literature on intellectual disability has undergone significant development during this period, research has focused on other aspects, such as mathematical communication. The lack of information related to mathematical curiosity in children with intellectual disability points to the potential need for further research to support the development of more holistic and immersive inclusive education for this group.

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