

The Landscape of Mathematics and Mathematics Education Research in Special Education: A Bibliometric Analysis

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Abstract

The main purpose of mathematics education in special education is to enable each student to learn and apply mathematical concepts by taking into account their individual needs. The aim of the study is to determine the place of publications including "special education and mathematics", "special education and mathematics education" in the literature and to present a panoramic perspective by revealing the dynamics of the field. In the study, bibliometric analysis was used, which offers an approach to accurately measure and analyse the publications examined in the database. Within the scope of the study, mathematics and mathematics education publications in special education provided important diagnostic data by presenting trends in past, present and future perspectives in the field. In this context, 487 articles were systematically analysed. It is a remarkable result of the study that most of the publications including "special education and mathematics", "special education and mathematics education" are found in special education journals. Another result is that the participants of the majority of the studies are students and children. In general, author collaborations between different groups are very few.

Keywords:

Mathematics, mathematics education, special education, bibliometric, Web of Science (WoS) database

Introduction

Mathematics is an indispensable communication tool that develops high-level thinking skills such as analytical thinking, reasoning and problem solving both within itself and in other disciplines. Mathematics plays a more important role today than ever before in understanding and exploring the world around us, and it is obvious that this importance will increase even more in the future (Özdemir & Kılıç, 2023). Baykul (2011) emphasises that mathematics is a vital tool not only in scientific fields but also in solving the problems we face in daily life. Mathematical competence is considered as one of the basic skills necessary for students to be successful both in their school life and in the future (Hatisaru, 2020). Being competent in mathematics is of great importance in terms of developing thinking skills (Özdemir & Kılıç, 2023). Even fields such as social sciences, music, literature and



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art require mathematical knowledge to understand concepts. This central role of mathematics makes it a critical discipline at every stage of the education system. For this reason, the teaching of mathematics in schools has been of considerable importance for many years (Schubring & Karp, 2014).

The rapid progress of science and technology in the world has changed the type of knowledge that individuals need in order for societies to achieve success. What is now expected from education is to provide individuals with the necessary competences to adapt to change, to be open to development, to adopt the spirit of entrepreneurship, to develop problem solving skills and to apply knowledge to new and real problems. Austin (1955) drew attention to the importance of developing comprehension in mathematics and emphasised that in addition to teaching vocabulary and problem solving methods, it is useful to have students read mathematical expressions. Similarly, Fuentes (1988) stated that learning mathematics depends on how it is read. Fuentes (1988) stated, 'In order for my students to realise their potential as mathematicians, they need to learn to understand mathematical texts consisting of numbers, abstract symbols and words'. Fuentes (1988) emphasises that every student can be successful with appropriate and timely corrective feedback. In line with this approach, the mathematics education programme in Türkiye is based on the principle that 'every child can learn mathematics' (Tatar & Dikici, 2008). Mathematics is considered to be one of the most important subjects that students should learn; however, it is seen as a difficult subject by many students due to its abstract nature. According to Abbasi et al. (2013), students' mathematics anxiety is an important factor that prevents them from developing their mathematical skills. Similar results and cultural problems are observed in the Turkish education system (Aydın & Doğan, 2012; Hatisaru & Erbaş, 2012).

Yıldızlar (2012) argues that the reason why mathematics is important at every stage of education and in all countries is that mathematics is an indispensable tool for scientific research and individuals' daily lives. Miller and Mercer (1997) emphasise that it is wrong to expect all children with similar intelligence levels in the same class to have equal abilities and learning speeds, because this would mean shaping the curriculum according to the children, not the curriculum according to the children. This approach is contrary to the basic principles of special education. The Ministry of National Education's 2006 Regulation on Special Education defines children with special needs as 'individuals who show significant differences from their peers in terms of their personal characteristics and educational competences for various reasons'. Children with special needs is a broad concept that includes children with learning and behavioural

difficulties, emotional or physical disabilities as well as those with intellectual differences (Özdemir & Kılıç, 2023). Children with special needs, like many children with normal development, may have difficulties in learning, applying and problem solving basic mathematical concepts and skills. Therefore, inadequate progress in mathematics skills becomes an important issue in terms of establishing appropriate educational programmes especially for students with special educational needs. In this context, measurement and assessment of mathematics skills are of great importance in terms of obtaining the necessary information (Glick et al., 1990; Mercer & Pullen, 2009). In addition, mathematics is a critical tool to enable individuals with special needs to cope with various situations they encounter in their daily lives. In particular, skills such as shopping in daily life require the ability to perform mathematical operations. Therefore, mathematical skills of individuals with special needs contribute significantly to their independent living (Karabulut & Yıkılmış, 2010).

According to the NCTM (2000) principle of equality in teaching mathematics, all individuals are supported and individuals with special needs should be taken into consideration. This principle is designed to ensure that every student has equal opportunities to develop mathematical thinking and problem solving skills. In particular, taking into account the educational needs of individuals with special needs requires appropriate support and adjustments to be made in the teaching process. This can be achieved by using different teaching strategies, tools and resources to meet individual needs. Furthermore, ensuring the accessibility of teaching materials and assessment methods creates a favourable learning environment that can help all students understand and apply mathematical concepts. Applying the principle of equity in mathematics teaching contributes to the creation of an inclusive and equitable educational environment that supports students to maximise their potential. Mathematics helps to improve mathematical performances in special education and provides equality in access to quality education for students with special needs by addressing learning and behavioural difficulties. However, it is known that there are significant inequalities in mathematics achievement between students with special needs and typically developing students (Hunt et al., 2022). For example, data from US and international assessments show that students with special needs experience persistent and pervasive inequalities of opportunity in mathematics learning. This situation reveals that over time, students with special needs have made only limited progress in mathematics achievement (National Assessment of Educational Progress, 2018; Programme for International Student Assessment, 2018). The inadequacy of special education teachers' mathematics preparation and lack of expertise are

related to the inequalities of opportunity that students face in the educational process (Rosas & Campbell, 2010). This is because the teacher is one of the most important school-based factors that positively affect student achievement (Rand, 2012). Therefore, research on teachers' mathematical knowledge is of great importance for the achievement of students with learning difficulties. However, research in the field of mathematics and special education generally focuses on the findings on improving students' performance rather than the effects of teachers' mathematical thinking knowledge and pedagogical skills on student performance. From this point of view, the study aimed to determine the place of studies on mathematics and mathematics education in special education in literature and it was thought that it would provide guidance for both students and teachers with special needs and for future research.

The study aims to answer the following questions in order to determine the place of publications including 'special education and mathematics', 'special education and mathematics education' in the literature and to present a panoramic perspective by revealing the dynamics of the field:

1. What is the general information about the publications on special education and mathematics and mathematics education?
 1. What are the findings about the number of publications?
 2. What are the findings about the researchers of the publications?
2. What is the structural and thematic development of publications on special education and mathematics and mathematics education?
 1. What are the most influential articles, sources and keywords in published studies?
 2. What is the thematic development and trend of keywords?
 3. What is the structure of cross-country and university co-operation networks?

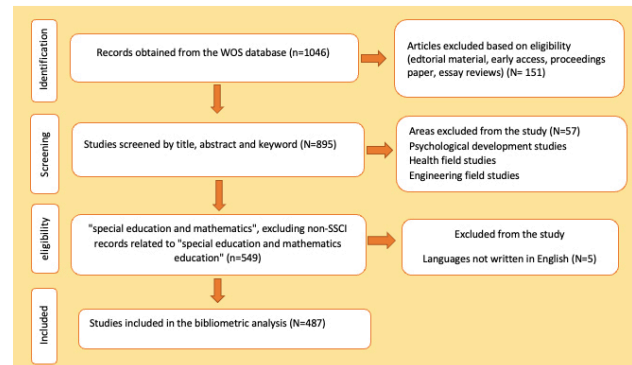
Considering the lack of studies in this field in literature and the potential for new ways by revealing certain characteristics and criteria of the studies, the study is considered to be important.

Method

In the study, bibliometric analysis was used, which offers an approach to accurately measure and analyse the publications examined in the database (Carmona Serrano et al., 2020a, 2020b). Bibliometric analysis, which has been used since the 1960s, allows systematic examination of studies with techniques such as keyword analysis, co-occurrence analysis,

cluster analysis and bibliometric maps, and provides information about the change of retrospective research over time (Pritchard, 1969; Song & Wang, 2020). It is also a method used to visualise trends in various research areas and to visually identify terms that are frequently used in studies on a particular topic or population (Bolaños et al., 2022). In order to provide comprehensive analyses in the study, the open source bibliometric R-Studio program package and R software were used (Aria & Cuccurullo, 2017; Aria & Cuccurullo, 2022). The bibliographic data in the study were obtained by using the advanced search feature in the Web of Science (WOS) database until January 2024. In the database search, parameters were determined by using the keywords "special education and mathematics", "special education and mathematics education". English-language publications were preferred in the studies and a search was made in the article section. English-language publications were preferred. The flow chart of the article selection process of the 487 data collected is shown in Figure 1.

Figure 1
Article process workflow chart



Findings

General Information

When the growth data of mathematics and mathematics education studies in special education are analysed, it is noteworthy that the first significant increase was in 2017 (Figure 2). In 2018 and 2019, there was a certain decrease in the number of studies published, but a high rate of increase occurred again in 2020. It is also noteworthy that there were no studies on the subject between 1981-1986 and 1988-1990.

According to Table 1, 887 different keywords were found in the studies published in 120 different sources (journals, conference proceedings, etc.) and these publications were cited at an average rate of 24.94. It was seen that 1093 authors contributed to these studies. 54 single-authored studies were published 45 times. The number of co-authors per study is (3.11). There are a total of 17813 references in the studies.

Figure 2
Changes in publications over the years

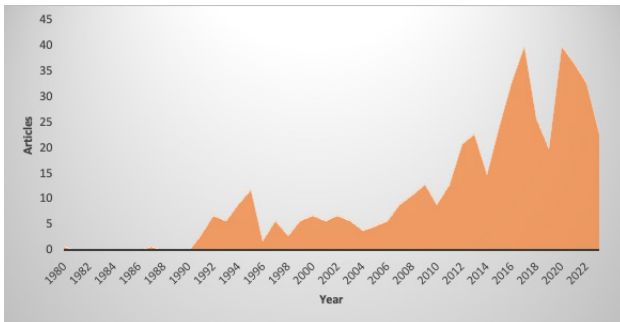


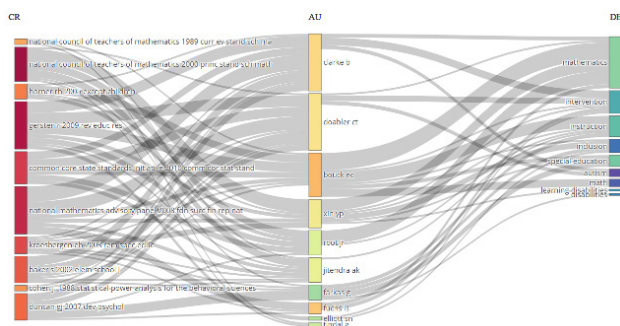
Table 1
Main Information

Description	Results
Articles	487
Period	1980-2023
Sources (Journals, Books, etc)	120
Annual Growth Rate %	7.56
Document Average Age	11
Average citations per doc	24.94
References	17813
Keywords Plus (ID)	887
Author's Keywords (DE)	1010
Authors	1093
Authors of single-authored docs	45
Single-authored docs	54
Co-Authors per Doc	3.11
International co-authorships %	9.035

Structural and Thematic Development

Three-fields diagram was used to provide an overview of mathematics and mathematics education studies in special education between 1980 and 2023. The Three-fields diagram visually presents the relationship between three main elements: authors, keywords and journals(Figure3).

Figure 3
Three-field diagram

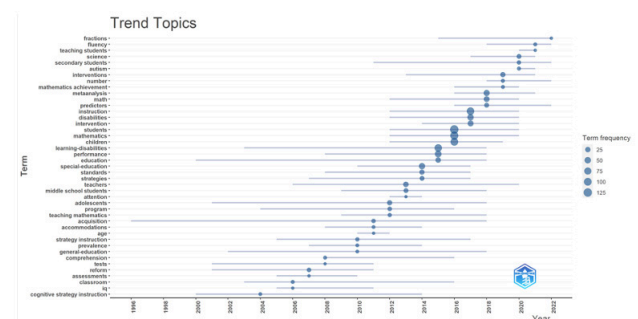


In the three-field diagram in Figure 3, the left column is journals, the centre column is authors, and the right column is keywords. The number of items in each field was chosen as 10 to make the graph more understandable. With the three-field diagram, the relationship between the authors who contribute the most to the field in the data set, the keywords they use the most and the most popular journals are presented. When the analysis of the studies is analysed, it is seen that the majority of the published studies are found in special education journals. It is noteworthy that the journals with the highest number of publications in the field are "Journal of Special Education" and "Remedial and Special Education". Bouck Ec is one of the most influential authors in the field and it is seen that the majority of the influential authors in the field use the keyword "mathematics" the most. The findings also show that Xin Yp and Root Jr have contributed significantly to the studies on special education and mathematics, special education and mathematics education.

Words Analysis

In the keyword trends analysis (trend topics), keywords, abstracts and titles are used to show the changes of publications over the years with a coordinate plan. With this analysis, it is revealed in which years the topics of the published studies have been realised. The correct selection of keywords, abstracts and titles is important and useful in terms of defining the framework of the research area. Researchers can easily access the publications they want in the literature with the help of keywords, titles and abstracts (Grant, 2010). By analysing trend topics, it is possible to observe the changes in the area and frequency values on the coordinate system (Figure 4).

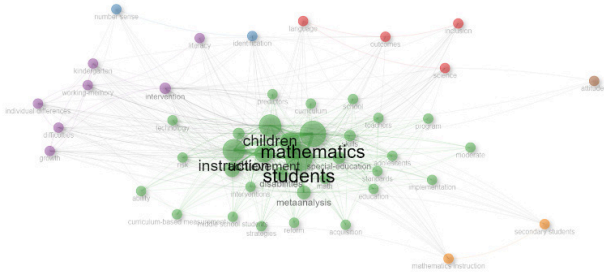
Figure 4
Analysing the trending topics of the field



When the frequency of using keywords according to the years of the studies is examined, it is noteworthy that the words "students", "mathematics" and "children" were popular in 2016, respectively. Then, it is seen that the words "instruction" in 2017 and "learning disabilities" in 2015 are frequently preferred in the studies.

Co-occurrence analysis is used to reveal the relationship between the most frequently used keywords in the studies more clearly and to visualise the frequency of co-occurrence of keywords and the network map. Figure 5 shows the network map analysis of 100 keywords in special education and mathematics, special education and mathematics education studies.

Figure 5
Co-occurrence network analysis



In the co-occurrence analysis given in Figure 5, it is seen that the keywords are classified in six different clusters. The large number of link thicknesses indicates the co-occurrence of keywords, and the size of the size indicates the size of the number of links. When the word network map is examined, it is seen that the cluster with the highest co-occurrence with other keywords, the largest size and the cluster with the highest number of elements is the green cluster. The most remarkable words of this cluster are "students", "mathematics" and "children" respectively. The network map of keywords in Figure 5 supports the keyword trends analysis in Figure 4.

Collaboration Networks

Collaboration networks reveal social networking and partnerships between individuals such as authors, countries and universities, or between organisations. When creating the collaboration network map, the biblioshiny parameter network layout for authors, countries and universities was set to automatic layout, 50 nodes, minimum two edges, 50 labels based on authors.

Figure 6
Authors collaboration network

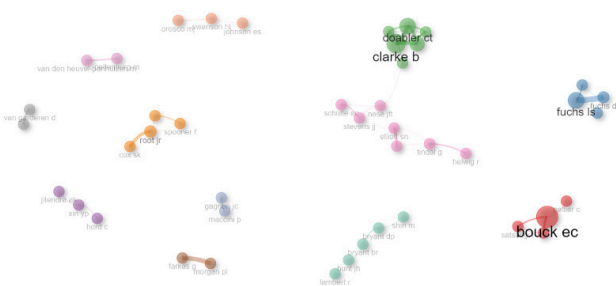


Figure 6 shows the authors' collaboration network. Collaborating authors are shown in the same colour. Considering the number of collaborations, the first three authors are Nese Jft, Shanley I and Elliott Sn, respectively. When evaluated according to the link thickness, the closeness of the collaboration between Fuchs Ls and Luchs D in the grey cluster draws attention.

Figure 7
Country collaboration network

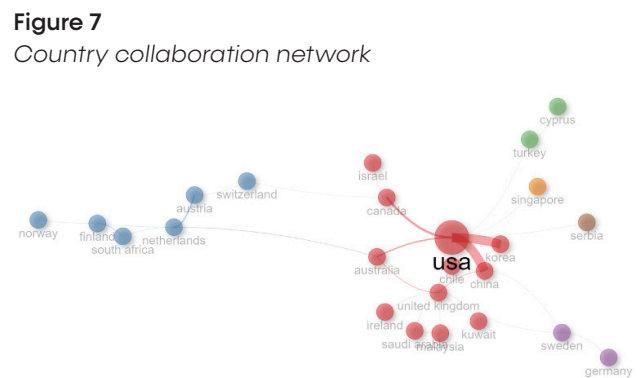
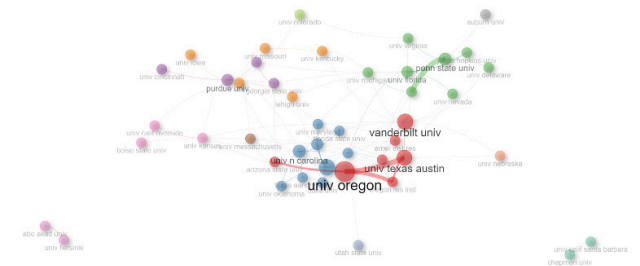


Figure 7 shows that many countries are in co-operation when we look at the studies on mathematics and mathematics education in special education. In the network map, the link thickness indicates the frequency of publication of the countries and the colours indicate the cluster they belong to. USA is seen as an active country with a high level of co-operation among other countries. At the same time, the cluster with the most cooperation between countries is the red coloured cluster. After USA, another country that is active in the co-operation network is United Kingdom. Clusters with at least two links consist of 24 countries in total.

Figure 8 shows the collaborations of universities or institutions working on mathematics and mathematics education in special education. University of Florida, Purdue University and Vanderbilt University are among the universities that stand out in terms of collaboration. When the collaboration network is analysed, there are clusters with at least two connections.

Figure 8
University collaboration network



Discussion and Conclusions

Mathematics and mathematics education studies in special education contribute to various advances in the field of education. This study is of great importance as it is the first comprehensive study that addresses the field of special education in a holistic manner in terms of mathematics and mathematics education studies in terms of subject and time. Looking at the growth rate of published studies, it is noticeable that there is a remarkable increase especially in 2017. When the development of publications is analysed in general, it can be said that studies have been progressing in recent years. This may be due to new research areas, educational reforms and the academic impact of special education on research on mathematics and mathematics education. In addition, the increasing interest in mathematics and mathematics teaching in the field of special education can also be shown as a reason. For example, as the foundations of inclusive education were laid in the 1950s, it became important to integrate students with special needs or disabilities into the 'normal' education system instead of 'special' education (Şimşek et al., 2019). With this approach, it is emphasised that students, teachers, learning environment, school management and families should develop sensitivity for students with special needs and be prepared in accordance with the needs of these students (Aktekin et al., 2017). Today, inclusive education is a process that aims to ensure that all children with special needs and those who have difficulty in accessing social, cultural, educational or vital opportunities have equal access to educational opportunities that can support their personal development with their peers and to eliminate the obstacles they face on this path (Aktekin et al., 2017; Çelik, 2017; UNESCO, 2005). In addition to these developments, the pandemic period in particular has caused learning losses in maths for disadvantaged students. For example, a study conducted in Belgium revealed that there was a significant decrease in the maths school averages of disadvantaged students (Maldonado, De Witte, 2020). It can be said that these situations have prepared the ground for many national and international studies conducted periodically. In addition, STEM (science-technology-engineering-mathematics) education is one of the subjects that has been frequently discussed worldwide in recent years and is thought to be effective in providing students with various skills. STEM education is an important approach that enables the development of competences such as creativity, critical thinking, problem solving and collaboration, which are defined as 21st century skills (Kennedy & Odell, 2014; Yıldırım & Altun, 2015). Considering that students with special needs need these skills throughout life, it is thought that the STEM approach will make a significant contribution to gaining many skills (Balçın & Yıldırım, 2020). When the literature is examined, it

is seen that the developments in STEM education contributed to the increase in awareness, especially in special education, and the popularisation of the STEM approach affected the studies conducted after 2018. In conclusion, based on these developments, it is possible to say that the studies affect awareness in special education and change the effectiveness of mathematics and mathematics education.

Mathematics and mathematics education studies in special education have an important place in the literature. The adoption of the importance of mathematics in special education has enabled the studies to become widespread. In addition, mathematics and mathematics education studies in special education have been effective in shaping educational policies and guiding academic studies. In addition, mathematics and mathematics education studies in special education are effective in shaping educational policies and guiding academic studies. When the studies conducted in this context were analysed, it was seen that the journal in which the most studies were published was "Journal of Special Education", the most influential author was "Bouck Ec" and accordingly, the majority of the influential authors in the field used the keyword "mathematics" the most. Bouck Ec, the most influential author, is a professor and researcher in special education. His research is directed towards investigating the effectiveness of different instructional strategies, interventions and technologies to improve the academic outcomes of students with disabilities, particularly in the area of mathematics. The fact that he has published widely in academic journals and written many books for teachers and educational professionals has made it inevitable that he will be recognised as one of the most influential authors in the study of mathematics and special education.

Social network analysis is applied in bibliometric studies to show the structural and thematic structure of the field (Johnson and Samakovlis, 2019; Mehraliyev et al., 2019). According to the findings of the study, different cluster classifications draw attention when word analysis results are evaluated. Considering the cluster classifications, link thicknesses and the size of the number of links in the clusters, it is noticeable that the most popular words used are "students", "mathematics" and "children". This is likely to be the result since the participants of the majority of the studies are students and children. Looking at the collaboration network map of social networking and partnerships between individuals or organisations such as authors, countries and universities, it can be said that there is a need for stronger collaborations in the field in order to increase the development of the field where there is a lack of collaborative work. The top three authors in terms of co-operation between authors are Nese Jft, Shanley I and Elliott Sn. It can be

said that the fact that Nese Jft, Shanley I and Elliott Sn are in the first three places in the collaboration between authors is due to the fact that they have similar interests and focus on the same study topics. In general, author collaborations between different groups are very few. In order to strengthen these collaborations, ideas can be shared at conferences, symposiums and congresses to contribute to the development of the field. When the co-operation between countries is evaluated, it is seen that the USA and then the United Kingdom are the countries with high and effective co-operation with other countries. Considering that the authors work in the USA, it is an expected result that USA ranks first in inter-author collaboration. It can be said that the main reasons for the concentration of mathematics and mathematics education research in special education, especially in universities in countries such as the USA and the UK, are strong legal regulations, funding sources, public awareness, interdisciplinary collaborations and educational reforms in these countries. Increasing awareness, especially in special education, and technological applications in mathematics are encouraging universities to do more research in these areas and increasing the research intensity of strong cultural traditions and international collaborations in these areas. According to the cooperation of universities or institutions, the University of Florida, Purdue University and Vanderbilt University are among the prominent universities in terms of cooperation. The University of Florida has a prestigious programme offering advanced mathematics education. Purdue University is also one of the leading institutions in the field of special education with a strong academic background and effective research programmes. In addition, Purdue University stands out with its studies on developing innovative approaches in special education and projects aiming to increase the success of students with disabilities in STEM fields such as mathematics and science. When these factors are taken into consideration, the strong positions of the universities in their respective fields and the deep knowledge they possess have led to co-operation as a natural outcome.

Limitations

The study is limited to the data obtained from the Web of Science database. Different data can be obtained by using Scopus database and Web of Science database together. The open source bibliometrix R-Studio programme package and R software were used in the study. Apart from this, different analysing software can be used. In addition, the study was limited to publications covering special education and mathematics, special education and mathematics education studies.

Conclusions and future direction

In the study, the bibliometric analysis process was developed based on a framework. With this framework, the articles were systematically analysed according to the workflow chart. Within the scope of the study, mathematics and mathematics education publications in special education provided important diagnostic data by presenting trends in past, present and future perspectives in the field. For example, the fact that most of the studies on the subject are found in special education journals is a remarkable issue that should be emphasised. In the studies, it is seen that the most popular words are student and child. However, since the teaching method and the planning of the learning process are also very important for children with special needs, the inclusion of teachers as participants in the studies will contribute to the best organisation of the teaching process. In addition, since the role of families in the education process of students with special needs cannot be ignored, studies that take into account the participation of families as well as teachers should be carried out. Technology has become an important supportive element in special education. For this reason, including innovative approaches such as digital tools and artificial intelligence in the teaching process and conducting more research on this subject will provide students with special needs with an individualised learning experience. However, since the teaching method and the planning of the learning process are also very important for children with special needs, the inclusion of teachers as participants in the studies will contribute to the best organisation of the teaching process. In addition, strengthening collaborations in terms of authors, countries and universities in order to increase the development of both special education and mathematics and mathematics education is an important result for future research. In this context, it is thought that researchers who want to work in the field of special education and mathematics, special education and mathematics education should cooperate with different countries and different universities. In addition, mathematics and mathematics education research in special education can include different disciplines such as psychology, educational technologies, linguistics, etc. to examine the mathematics learning processes of students with special needs in more depth.

Data availability Information is available from the author upon request.

Declarations

Conflicts of Interest Conflicts of interest were not disclosed by the author.

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