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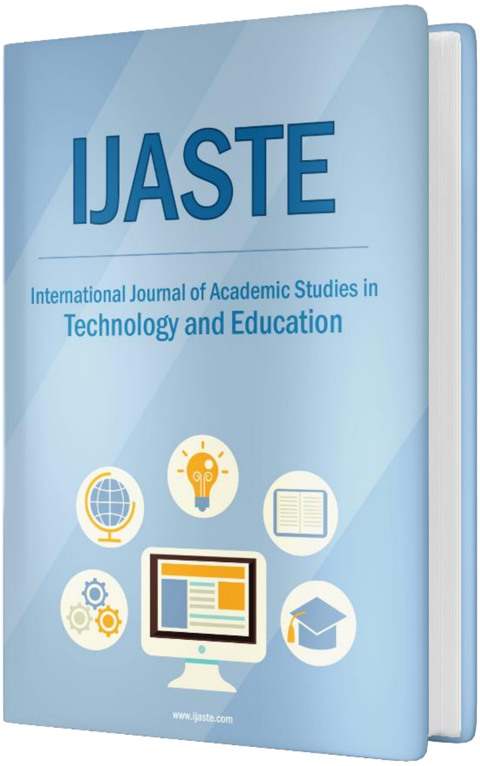

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Investigating the Research Trends of Articles on Science Education and Artificial Intelligence

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Abstract

In the current era, the integration of artificial intelligence applications into education systems is inevitable. One of the fields that is expected to be in contact with the concept of artificial intelligence the most is science education. This study was carried out with the aim of revealing the research trends of articles on science education and artificial intelligence and bringing the bibliometric profile to the literature. Descriptive research design, one of the quantitative research models, was used in the study. In the analysis step, bibliometric analysis method was preferred. Web of Science Core Collection was used as the database and VOSviewer was used as the network analysis program. The findings of the study were obtained by analyzing 89 articles on science education and artificial intelligence. As a result of the research, the most productive author in the articles on the relevant subject area is Xiaoming Zhai, the journal is Frontiers in Education, the institution is University System of Georgia, and the country is the USA. In addition to these findings, it was determined that the most frequently used keyword in the articles in the related subject area was "artificial intelligence".

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Introduction

Traditional learning models are being reexamined and critically scrutinized in an era marked by rapid technology breakthroughs and a massive multiplication of information (Anderson & Rivera Vargas, 2020; Collins & Halverson, 2018). One theory that has emerged from this re-evaluation is connectivism. It emphasizes the importance of digital technologies and the interconnectedness of information in the modern world (Siemens, 2005). As a relatively recent learning theory, connectivism has become a significant framework for understanding the impact of technology on education. According to connectivism, learning is not just an individual process; it is heavily influenced by the connections and networks formed online (Downes, 2007). It means that the individual's learning process does not only occur with his or her knowledge and experiences but is also shaped by contributions from online environments and tools that technology has brought to our lives. This stands in contrast to traditional learning theories, which typically center on individual cognition or behavior. Therefore, in the digital age, connectivism acknowledges that knowledge is widely dispersed and continually evolving, necessitating learners to adeptly navigate and utilize these networks. This paradigm shift calls for a departure from the conventional, instructor-centric classroom towards more learner-centered, collaborative, and technology-enhanced approaches. Blended learning, which integrates both face-to-face and online elements, exemplifies this evolution by enabling learners to interact with content, peers, and educators through diverse modalities (Hrastinski, 2019; Kaur, 2013). Moreover, connectivism's emphasis on the role of technology in learning aligns with the potential applications of artificial intelligence (AI) in education. Both highlight the transformative impact of digital tools on educational practices and the improvement of learning outcomes (Spiess et al., 2021). This intersection signifies ongoing progress towards more dynamic and responsive educational environments. AI has the potential to revolutionize education by providing personalized and adaptive learning experiences for students. AI-supported systems can identify learning patterns and adapt teaching content to meet individual needs (Chen et al., 2015; Roll & Wylie, 2016). Accordingly, the utilization of artificial intelligence in education aligns with the fundamental principles of the connectivist approach, influencing students' control over their learning processes and enabling them to make various connections between different sources of information (Roll & Wylie, 2016).

AI has the capacity to transform various aspects of education, from personalized learning to intelligent tutoring systems (Pratama et al., 2023) and has the potential to change traditional patterns of learning and teaching. The intersection of connectivism and AI in education carries promising implications for science education. By eliminating the difficulty of teaching lessons in a real classroom environment using traditional methods and taking into account each student's individual differences, AI can provide personalized learning experiences by adapting content to individual students' needs and learning pace, making complex scientific concepts more accessible. It provides data-driven feedback to teachers and curriculum developers by identifying areas where students struggle and providing targeted support. However, AI can overcome the barrier of perceiving science and mathematics courses as difficult subjects (Leyva et al., 2022), improving accessibility and inclusiveness, and enabling students with different learning needs to benefit from science education (Tapalova & Zhiyenbayeva, 2022). Innovative tools like virtual labs and simulations can allow students to engage with scientific experiments in a practical and hands-on manner. Furthermore, AI can support teachers by automating routine tasks, giving them more time to focus on facilitating deeper understanding and critical thinking in science subjects. This integration of AI into science education can not only improve learning outcomes but also can prepare students for a future where technology plays a central role. With all this awareness, the application of AI in education has garnered increasing attention in recent years. Even a simple search on Google Scholar with the search code "artificial intelligence" between 2020 and 2024 yields 1,290,000 results. If we add "education" to this code, we encounter 490,000 results between these years. In every field, even in different branches of education, studies using AI are undoubtedly important in understanding its nature and effects. One of these branches is science education, which we can view as a steppingstone for AI and other technological advancements. Understanding the landscape of AI research in science education is crucial for identifying trends, gaps, and future directions. Bibliometric analysis provides a systematic method to analyze the vast body of literature, offering insights into the development and impact of AI in science education. That's why this study aims to conduct a bibliometric analysis of research on artificial intelligence in science education. By examining publication patterns, influential authors, and key research topics, the study seeks to map the evolution of AI research in science education and highlight emerging trends and areas for future investigation.

Theoretical Framework

The History of Artificial Intelligence

Alan Turing's 1950 paper, "Computing Machinery and Intelligence," laid the foundations for artificial intelligence and questioned whether machines could think. In this paper, although the current accessibility and wide applicability of artificial intelligence might seem like just a theory, Turing proposed the "Turing Test" to determine whether a machine could exhibit human-level intelligence (Turing, 1950). Following this notable work, research in the field of artificial intelligence and its development progressed rapidly. Specifically, the concept of AI was first introduced in 1955 by John McCarthy, a mathematician who is also known for organizing a conference on AI the following year (Brynolfsson & McAfee, 2017). Shortly thereafter, a platform was established to discuss the capacity of machines to exhibit human-like intelligence. One of the discussions, led by economist Herbert Simon in 1997, was quite bold. According to him, computers would surpass human chess abilities within a decade (Frantz, 2003). Similarly, in 1974, cognitive scientist Marvin Minsky believed that artificial intelligence would be largely solved within a generation (Minsky, 1974). Since 1975, AI has progressed from expert systems to artificial neural networks, big data, and deep learning breakthroughs

(Rumelhart et al., 1985); became widespread in various fields like autonomous vehicles and healthcare in the 2010s (Hengstler et al., 2016); and rapidly advanced in the 2020s with a focus on chatbots and ethical regulations (Larsson, 2020; Shin et al., 2021). To summarize, AI, a topic of discussion for nearly 70 years, has reached the stage where it is realizing some of the predictions made in the past. However, debates about what more lies ahead continue.

The Transformative Role of Artificial Intelligence in Science Education

As can be seen, AI has emerged as a transformative force in various domains, and its impact on science education is particularly profound. Even before AI had reached its current level of development and widespread use, researchers in the 1980s, such as Good (1987) and Hurd (1988), discussed its potential effects and the role of science education in leveraging this technology. These early studies underscored the importance of using AI in science education and highlighted the need to train individuals through science education to advance AI technology. They argued that integrating AI into science education not only enhances the learning experience but also prepares students to contribute to the development of AI technologies. The importance of combining science education with AI can also be clearly seen when we compare it with the goals of integrated STEM (Science, Technology, Engineering and Mathematics) education over the last two decades. In today's increasingly technological world, it is no longer sufficient to know science and mathematics in isolation. Instead, the integration of technology and engineering with science and mathematics is essential for keeping pace with technological advancements (Hamal et al., 2022; Miller, 2017). AI, as a product of this technological evolution, plays a crucial role in this integration. Therefore, science education, which we believe is important in integrating rapid technological progress into education and understanding technological developments, should not be left behind.

Through simulations, virtual labs, and intelligent tutoring systems, AI can create interactive and immersive learning environments that make complex scientific ideas more accessible and engaging for students. Therefore, AI's impact on science education extends beyond personalized learning; it also equips students with the skills necessary to thrive in a technology-driven future. According to a study, AI has the potential to revolutionize STEM higher education by transforming teaching and learning methodologies, curriculum design, student engagement, assessment practices, and institutional strategies (Nagaraj et al., 2023) AI-based systems can analyze student data, identify individual strengths and weaknesses, and tailor learning materials to cater to each student's unique needs (Mavroudi et al., 2017).Moreover, this entegration can significantly enhance student engagement, improve learning outcomes, and reduce dropout rates. AI-based tools can provide instant feedback, allowing students to receive real-time guidance and identify areas for improvement (Kamalov et al., 2023). This can lead to more efficient and effective learning, as students can receive immediate support and guidance to address their learning gaps. Additionally, AI-powered educational robots have garnered attention in the field of science education (Yang et al., 2023). Although research on artificial intelligence is in its early stages, it has been suggested that chatbots in science education can enhance learning experiences, improve learning outcomes, and increase student engagement and interest in the course (Deveci Topal et al., 2021).

In summary, the application of AI to education is seen as a technology with high potential that will increase the quality of education and learning in many respects.The motivation behind this study stems from the observation that, despite the transformative potential of AI, there remains significant uncertainty about how best to integrate it into education. As Brynjolfsson and McAfee (2017) aptly put it, "*You've been told it will transform everything. You've been told you need to invest in it. But you haven't been told how. Start here.*" AI is still a nascent topic in the field of education, with many attempting to integrate it but lacking clear guidelines and methodologies. Therefore, this study aims to examine the research trends in articles focusing on science education and AI by analyzing the bibliometric profile of publications in this area. By investigating these trends, this study seeks to provide valuable insights into the current state of research in this emerging field, helping educators, researchers, and policymakers make informed decisions on effectively integrating AI into science education. This can lead to more effective educational practices and better prepare students for a technologically advanced future. The central research question guiding this study is: What are the research trends in articles on science education and AI?

The sub-problems examined in the study in the context of the research question are:

- How is the publication trend in the fields of science education and artificial intelligence distributed over the years?
- In which languages are publications on science education and artificial intelligence available?
- In which research areas are publications on science education and artificial intelligence being studied?
- Which journals are the most productive for publications on science education and artificial intelligence?
- Which countries are the most productive in publishing articles on science education and artificial intelligence?
- Which countries have the highest level of collaboration in publications on science education and artificial intelligence?
- Which institutions are the most productive in publications on science education and artificial intelligence?
- Who are the most productive authors studying on science education and artificial intelligence?

- Which documents have the highest number of citations in research on science education and artificial intelligence?
- Who are the authors with the highest number of citations in articles on science education and artificial intelligence?
- Which journals have the most citations for articles on science education and artificial intelligence?
- What are the keywords used in articles on science education and artificial intelligence?

Method

Research Model

The aim of the study is to reveal the research trends of articles on science education and artificial intelligence. In line with the research purpose, descriptive research model, one of the quantitative research methods, was preferred in this study. Descriptive research is research that aims to describe the characteristics of the study sample or the relationship between situations and events observed by the researcher (Siedlecki, 2020; Vaismoradi et al., 2013). In the study in which descriptive research model was used, bibliometric analysis method was preferred as the analysis method. Bibliometric analysis method is a quantitative analysis method that presents the bibliographic characteristics of the literature on the relevant subject with numerical data in the historical process (Hawkins, 2001). Bibliometric analysis method is an analysis method that offers the opportunity to reveal and examine the research trend and bibliometric profile on the relevant subject at a global level based on the outputs obtained through analysis programs of scientific publications published in various databases. With the bibliometric analysis method, it is possible to examine the research trend of a certain concept or a journal from past to present. In this context, it has been a frequently preferred method especially in recent years in studies aimed at examining the research profile or research trend (Donthu et al., 2021; Ellegaard, 2018).

Research Data

Web of Science Core Collection (WoS) was preferred as the database to collect data in order to reveal the research profile and examine the trend of articles on Science Education and Artificial Intelligence. VOSviewer program was used as a network program for the analysis of bibliometric data. In order to create the research data, the researchers searched the Web of Science Core Collection database with the keywords "science educat*" and "artific* intelligen*". In the study, the scientific studies on artificial intelligence were focused on those related to science education. The researchers were interested in the research tendency of the articles related to artificial intelligence and science education. Therefore, the keywords "science educat*" and "artific* intelligen*" were used in the search. The researchers carried out the first search in the database with keywords in the topic heading. When topic is preferred as the search heading, the title, abstract, keyword plus, and author keywords of the publications registered in the database are searched. This heading was preferred to narrow the area to be searched and to reach highly relevant publications with the selected keywords. In the research, articles were analyzed among scientific publications. Scientific articles were preferred in the study because they are considered to be the most representative type of academic publications as they have the most frequent publication intervals and they provide original, comparable data suitable for bibliometric method analysis (Prahani et al., 2024). The data set of this study consists of 89 articles obtained after the studies eliminated with appropriate filtering selected by the researchers in the search made with the selected key concepts in the WoS database.

Data Collection Process

The data for this study were created in June 2024. The study data consists of articles published in the Web of Science (Web of Science Core Collection provided by Clarivate Analytics) database on the relevant subject. The Web of Science database is one of the most popular and widely used databases that publishes studies from many different disciplines, is sensitive to the reliability of the scientific studies it publishes, publishes scientific studies with high impact power, has a wide coverage network, and has high popularity (Goodman, 2007; Zyoud et al., 2017). For these reasons, Web of Science was preferred as the database in this study. At the beginning of the data collection process, the researchers searched the WoS database with the keywords "science educat*" and "artific* intelligen*" in the topic heading. The first search resulted in 179 scientific publications. Among 179 scientific publications, articles were filtered. As a result of the filtering, 111 articles were found. It was determined that 22 of the 111 articles were published in 2024. Since the aim of the study was to reveal the research trends of scientific articles on science education and artificial intelligence, the data for 2024 were not included in the study. Since interpreting the data of a year that has not yet been completed may make the bibliometric profile and trend of the relevant subject open to misinterpretations, the data of 2024 were not included in the study. With the exclusion of 2024 data, the remaining 89 articles constitute the data of the study. The data collection and filtering process is presented in Figure 1.

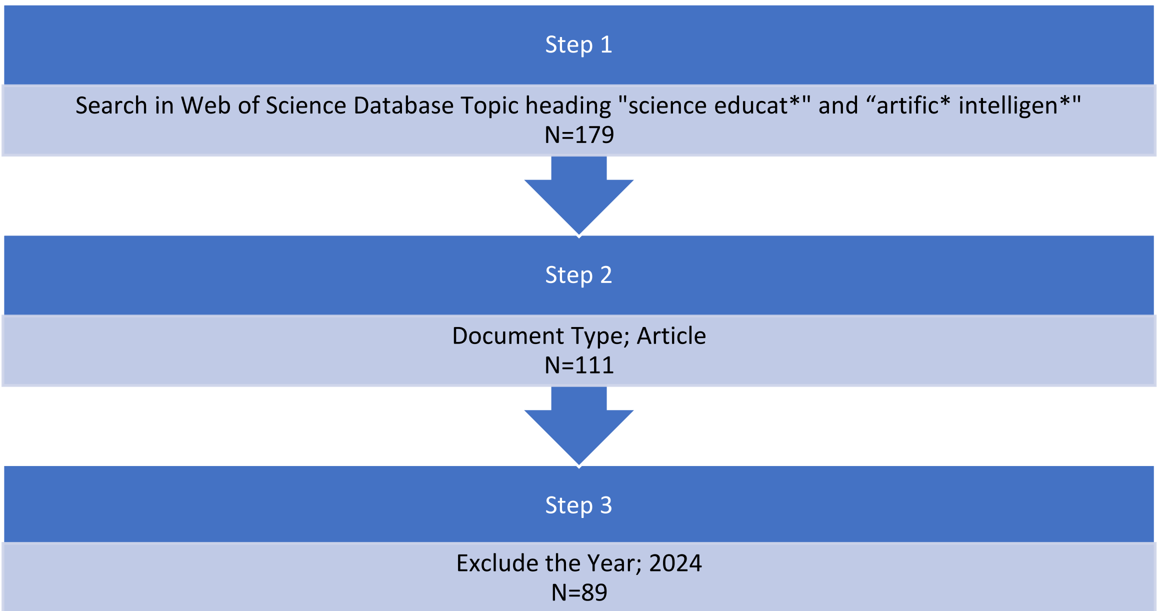

Figure 1. Data Selection Process

Data Analysis

With the completion of the data collection process, the data analysis step was started. The study is a descriptive study. Bibliometric analysis was preferred as the analysis method. In this context, VOSviewer, one of the network programs, was used to analyze the bibliometric data that constitute the data set of this study. VOSviewer is a network program that can visualize data and uses the Visualization of Similarities (VoS) algorithm for this visualization process. The VOSviewer network analysis program creates high-quality visual materials, making large-scale scientific network graphs easier to understand (Sinkovics, 2016; Van Eck & Waltman, 2009; Van Eck & Waltman, 2017). For these reasons, VOSviewer program was preferred in the study. As a result of the analysis made with the VOSviewer program, information such as authors, journals, countries with the most documents in the literature on the relevant subject, as well as information on the number of citations, relationship strengths and keywords can be presented. The VOSviewer program can make visualization with co-occurrence maps in the presentation of this information. Co-occurrence maps match the size of the circle or the shape it uses with features such as the number of publications in the literature, the number of citations, and can show the links and relationships between the shapes. Likewise, the larger and more central the shape used in the co-occurrence maps presented in the analysis of keywords, the more frequently the keyword is used. The larger the shape, the more popular the keyword is. The stronger the relationship between two key concepts in the keyword co-occurrence map, the more frequently the two key concepts are used together (Pei et al., 2021; Van Eck & Waltman, 2014).

Results

Year Distribution of Scientific Articles on Science Education and Artificial Intelligence

Articles on science education and artificial intelligence are analyzed, it is seen that the first article was published in 1985. The first publication published in 1985 was an article titled "Artificial intelligence and expert systems research and their possible impact on information science education" written by Harold Borko. The study was published in the journal "Education for Information". The study focuses on expert systems and artificial intelligence and investigates their impact on information systems. The distribution of the number of publications by years is presented in Chart 1.

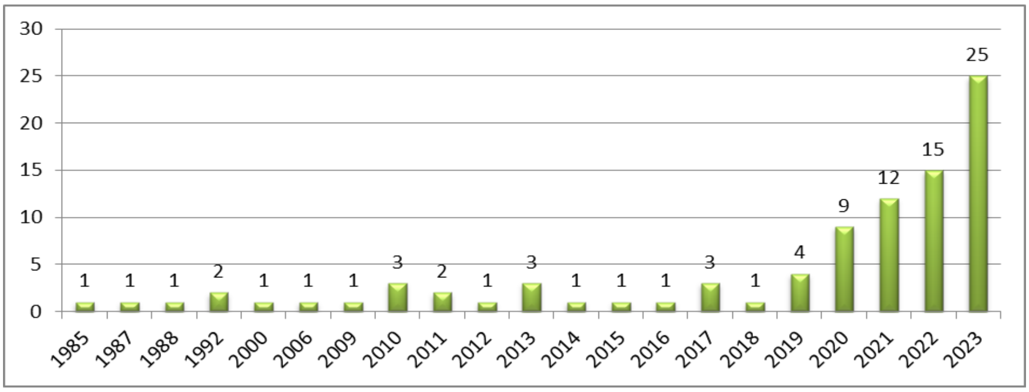

Chart 1. Annual Distribution of Publications on Science Education and Artificial Intelligence

When the years and numbers of publications are analyzed, it is seen that in some years no publications were published, while in some years (1985, 1987, 1988, 2000, 2006, 2009, 2012, 2014, 2016 and 2018) only one publication was published. When the year distribution data of the articles are analyzed, the trend in the number of articles on the relevant subject for the last 39 years, except for the year 2024, emerges. When the 39-year research trend is analyzed, it is seen that the year with the highest number of publications is 2023. When the data are analyzed, it is possible to say that the interest in studies on science education and artificial intelligence started in the mid-1980s, but this interest disappeared in the 1990s. In the 1990s, only two articles were published in the preferred database in 1992. When the graph is analyzed, while there is a variable number trend before 2018, a steady increase in publications is observed after 2018. After 2020, the number of publications increased significantly compared to previous years. This situation can be interpreted as the main popularity in the relevant subject gained in 2020 and after.

Distribution of Languages in which Scientific Articles on Science Education and Artificial Intelligence are Published

Language of publication of the articles on science education and artificial intelligence is analyzed, it is seen that the majority of the articles are published in English (Chart 2).

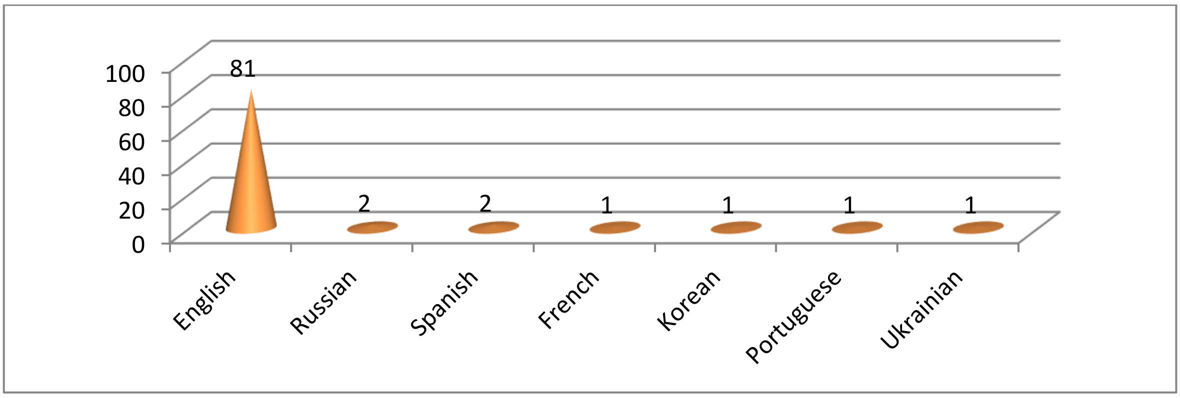

Chart 2. Language Distribution of Publications on Science Education and Artificial Intelligence

When the data are analyzed, it is seen that articles on science education and artificial intelligence are published in 7 different languages in the WoS database. In the 39-year period from 1985 to 2024, 91.01% of the articles (81 articles) were published in English. Of the remaining 8 articles, 2 were published in Russian and 2 in Spanish. The remaining 4 articles were published in French, Korean, Portuguese and Ukrainian. Since English is the most widely used language in academic and spoken language, it is an expected result that the majority of the articles are in English.

Distribution of Scientific Articles on Science Education and Artificial Intelligence by Research Areas

Scientific articles on science education and artificial intelligence cover 23 distinct research fields in the WoS database (Chart 3).

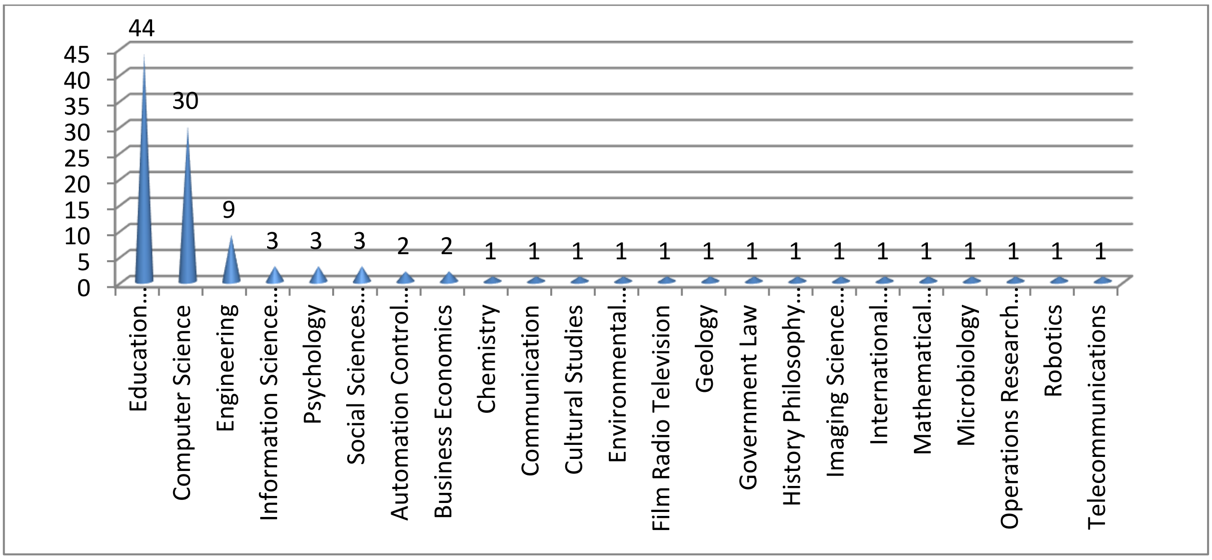

Chart 3. Distribution of Research Fields in Scientific Articles on Science Education and Artificial Intelligence

When the data are analyzed, it is seen that the articles on science education and artificial intelligence are mostly (49.43%) studied in the field of educational research. In the field of educational research, 44 articles on science education and artificial intelligence were studied. Educational research is followed by Computer Science (30 articles), Engineering (9 articles), Information Science Library Science (3 articles), Psychology (3 articles) and Social Sciences Other Topics (3 articles).

Distribution of Productive Journals for Scientific Articles on Science Education and Artificial Intelligence

Data on the journals publishing articles related to science education and artificial intelligence reveal a total of 71 journals in the database. To enhance data readability, the top 20 journals and their publication counts are presented in Chart 4.

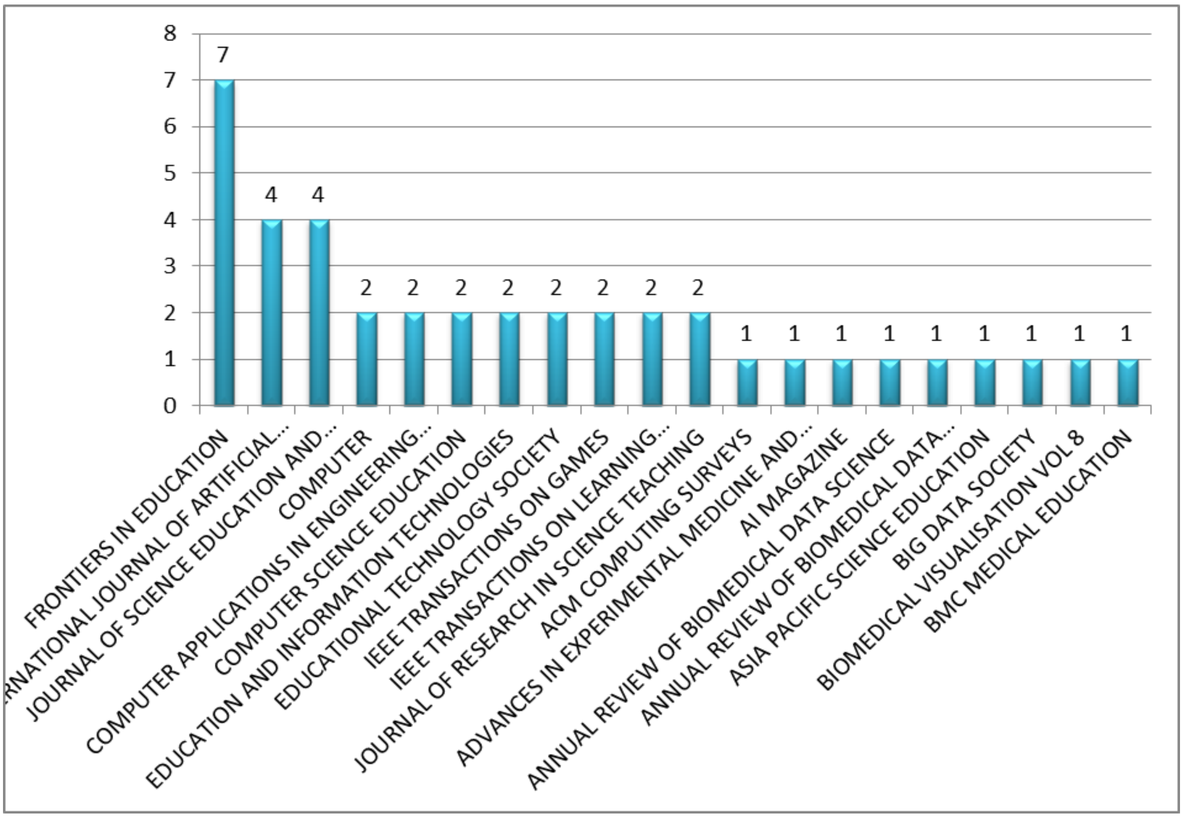

Chart 4. Distribution of Most Productive Journals in Science Education and Artificial Intelligence Research

The most productive journal in the field of science education and artificial intelligence is "Frontiers in Education." This journal focuses on topics such as digital learning innovations and STEM education, publishing a total of 7 articles in the area. Next in productivity are the journals "International Journal of Artificial Intelligence in Education" and "Journal of Science Education and Technology," each publishing 4 articles. The list of the most productive journals continues with "Computer," "Computer Applications in Engineering Education," "Computer Science Education," "Education and Information Technologies," "Educational Technology Society," "IEEE Transactions on Games," "IEEE Transactions on Learning Technologies," and "Journal of Research in Science Teaching," each contributing 2 articles.

Distribution of Productive Countries for Scientific Articles on Science Education and Artificial Intelligence

The analysis of the most productive countries for scientific articles on science education and artificial intelligence reveals 42 countries listed in the WoS database. For clarity, the top 20 most productive countries in this field are presented in Chart 5.

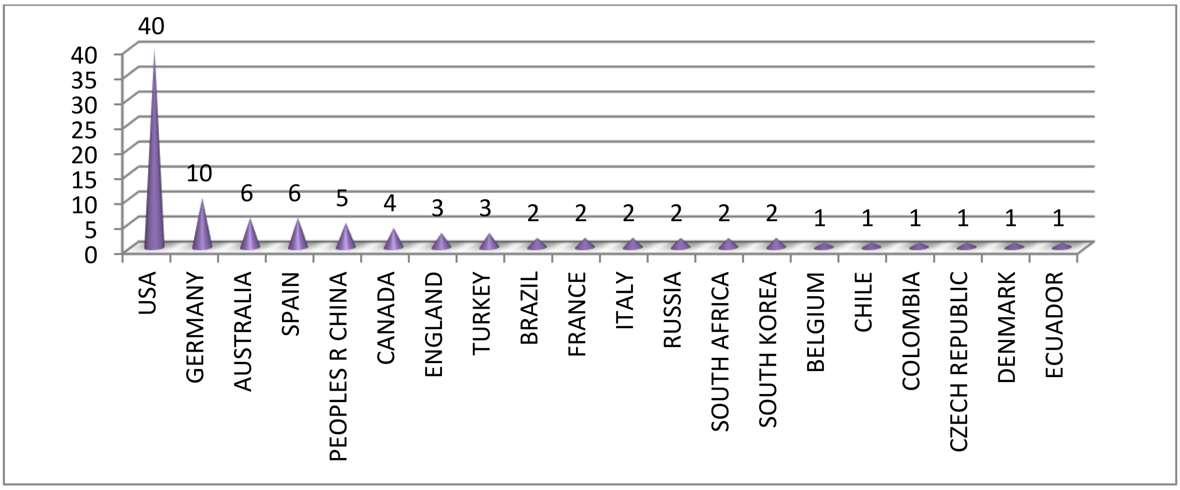

Chart 5. Distribution of Most Productive Countries for Scientific Articles on Science Education and Artificial Intelligence

The United States is the most prolific country in publishing articles on science education and artificial intelligence, with a total of 40 articles (44.94%) in this field. The integration of technological systems into science education began in the USA, which is recognized as a pioneer in this integration. This prominence reflects the significant emphasis placed on technology-supported structures within the U.S. education system. Germany follows as the second most productive country with 10 articles. Australia (6), Spain (6), and China (5) are ranked third, fourth, and fifth, respectively.

International Collaboration (Country) Distribution in Scientific Articles on Science Education and Artificial Intelligence

International collaboration in scientific articles on science education and artificial intelligence involves 42 different countries. The top 20 countries with the highest collaboration strength are shown in Chart 6.

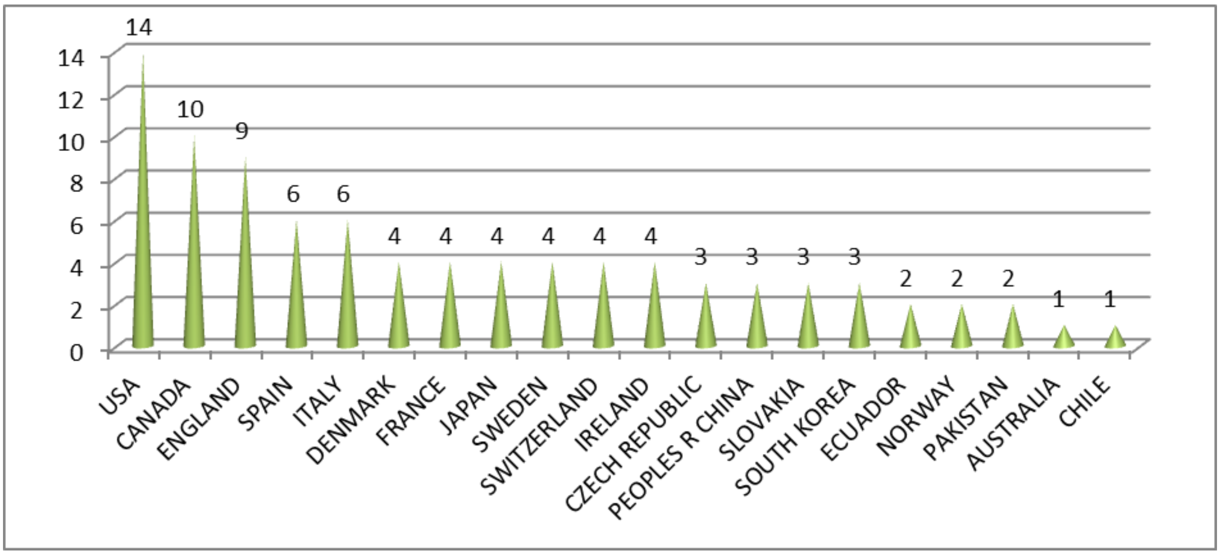

Chart 6. Collaboration Strength among Countries in Science Education and Artificial Intelligence Research

When the data are analyzed, it is seen that among the countries with publications on the relevant subject, the USA is the country that collaborates the most and has the highest strength of relationship. This is an expected result since the USA has the highest number of publications. The USA is followed by Canada (10), England (9), Spain (6) and Italy (6). Twenty-three of the countries with publications on the related subject maintain a collaborative relationship with each other. The co-occurrence map of the cooperation between countries is presented in Figure 2.

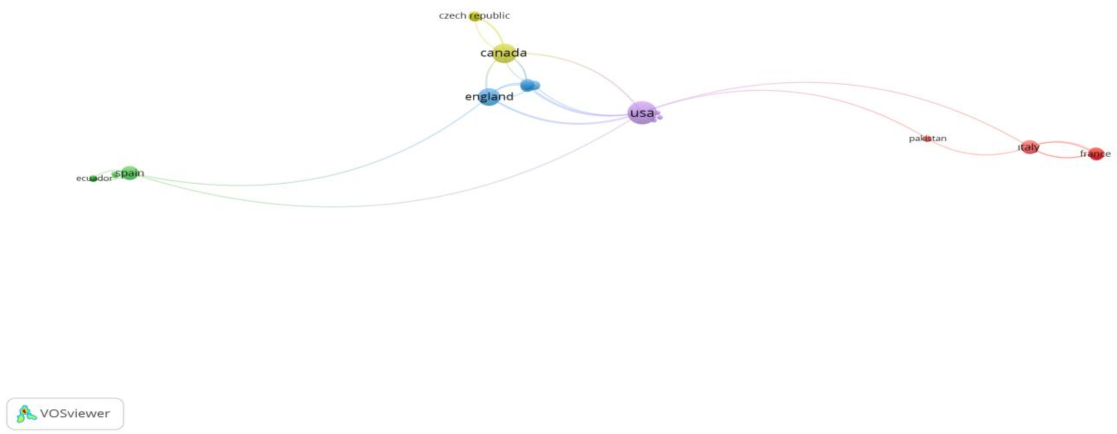

Figure 2. Co-occurrence Map of International Publication Collaborations

Distribution of the Most Productive Institutions in Scientific Publications on Science Education and Artificial Intelligence

Analysis of productive institutions in science education and artificial intelligence research reveals 173 institutions listed in the WoS database. The top 20 most productive institutions are presented in Chart 7.

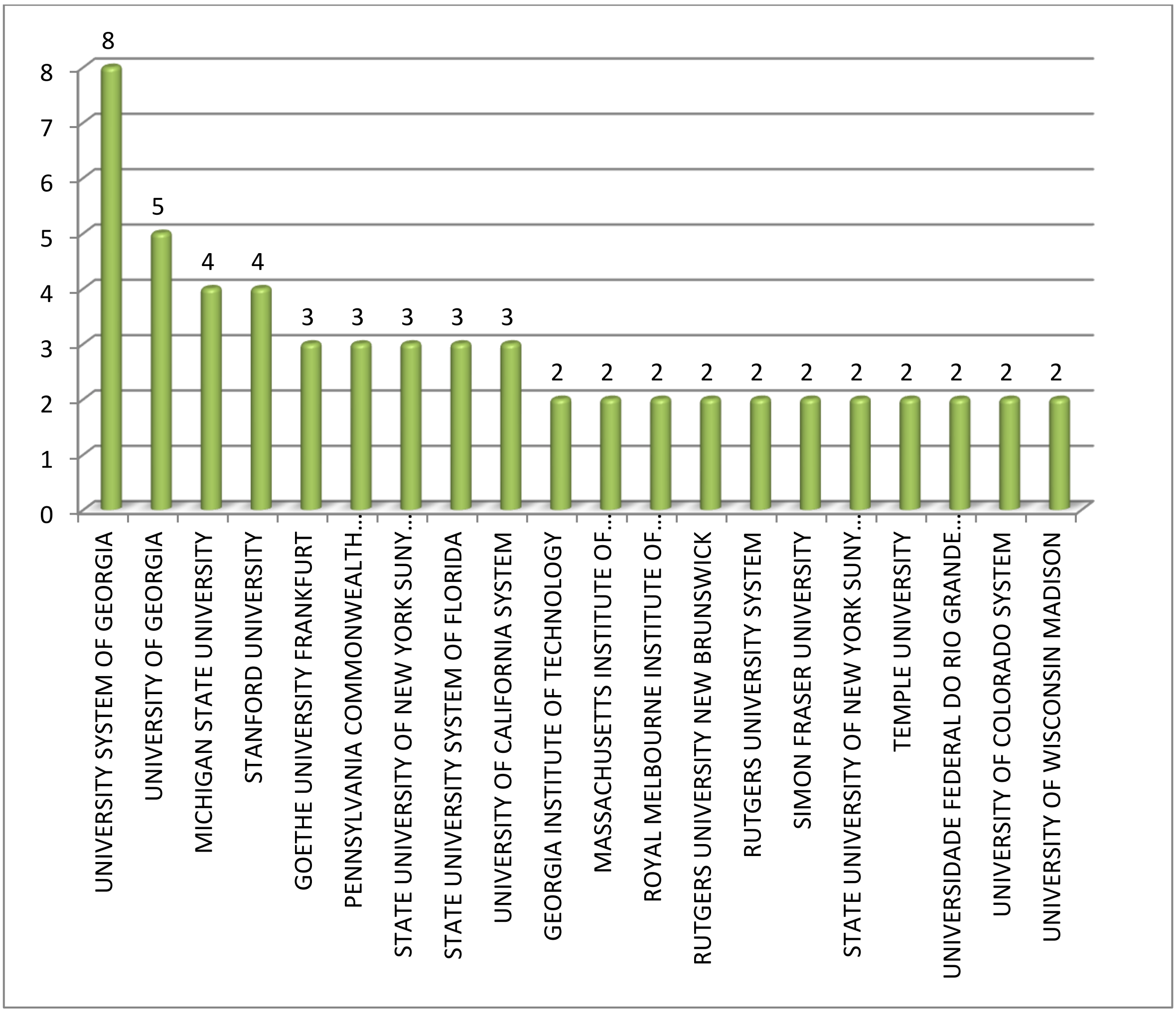

Chart 7. Leading Institutions with Publications on Science Education and Artificial Intelligence

The analysis of institutions publishing articles on science education and artificial intelligence reveals that the University System of Georgia is the most prolific, contributing to 8 publications in this field. The second most productive institution is the University of Georgia, with 5 publications. Other notable contributors include Michigan State University and Stanford University, each with 4 articles, and Goethe University Frankfurt, Pennsylvania Commonwealth System of Higher Education, State University of New York SUNY System, State University System of Florida, and University of California System, each with 3 articles. Among the institutions with at least 3 publications, 8 out of 9 are located in the United States. The sole institution outside the U.S. is Goethe University Frankfurt in Germany. This distribution underscores the prominence of U.S. institutions both in terms of publication volume and collaborative efforts in this field.

Distribution of the Most Prolific Authors in Science Education and Artificial Intelligence Research

Analysis of the most prolific authors in science education and artificial intelligence research reveals 315 researchers in the Web of Science database. To enhance readability, the top 20 authors are presented in Chart 8.

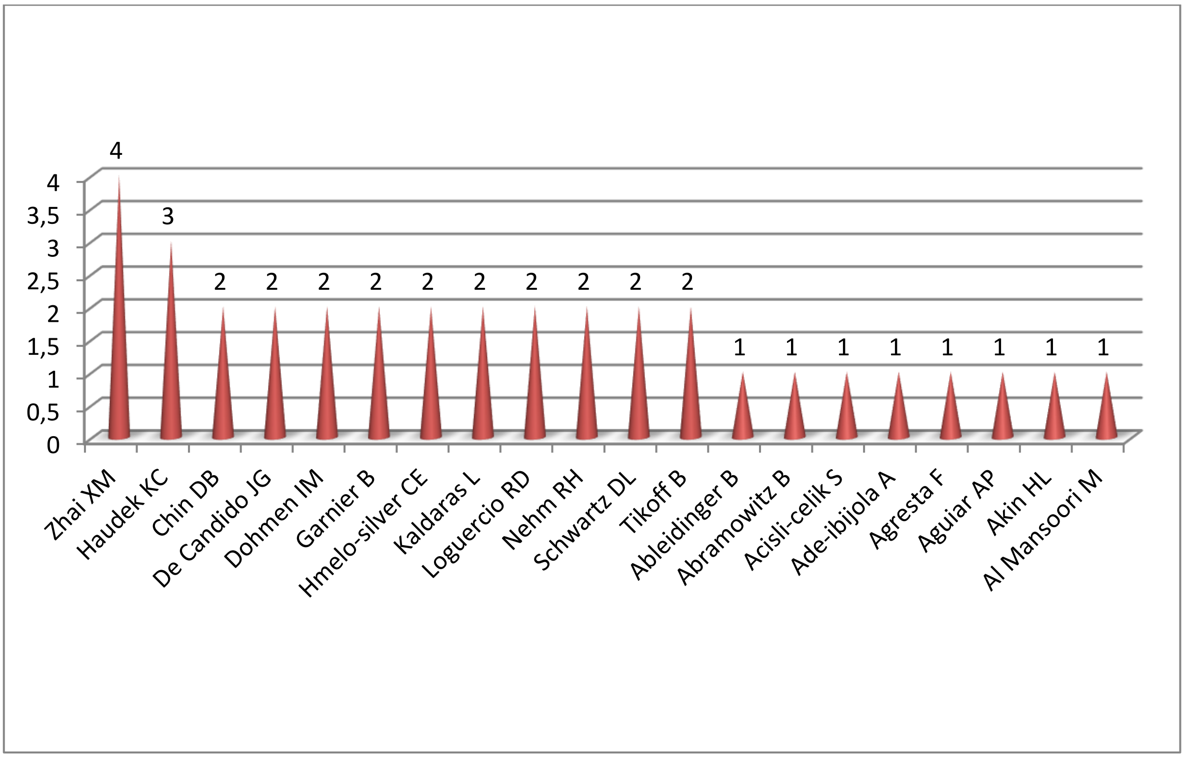

Chart 8. Prolific Authors and Their Number of Publications in Science Education and Artificial Intelligence

The most prolific author in the field of science education and artificial intelligence is Xiaoming Zhai, who has published four articles on this topic. Zhai is affiliated with the University of Georgia, which ranks as the second most productive institution in this field. The second most prolific author is Kevin C. Haudek, with three articles. Haudek is affiliated with Michigan State University, the most productive institution in this domain.

Findings Related to Citation Information of Scientific Articles on Science Education and Artificial Intelligence

The citation information for articles on science education and artificial intelligence was initially examined on a document basis. According to the analysis results, the document with the most citations is the study titled "Examining Science Education in ChatGPT: An Exploratory Study of Generative Artificial Intelligence," written by Grant Cooper and published in the Journal of Science Education and Technology in 2023. This study has 149 citations. The top 20 most cited documents are presented in Chart 9.

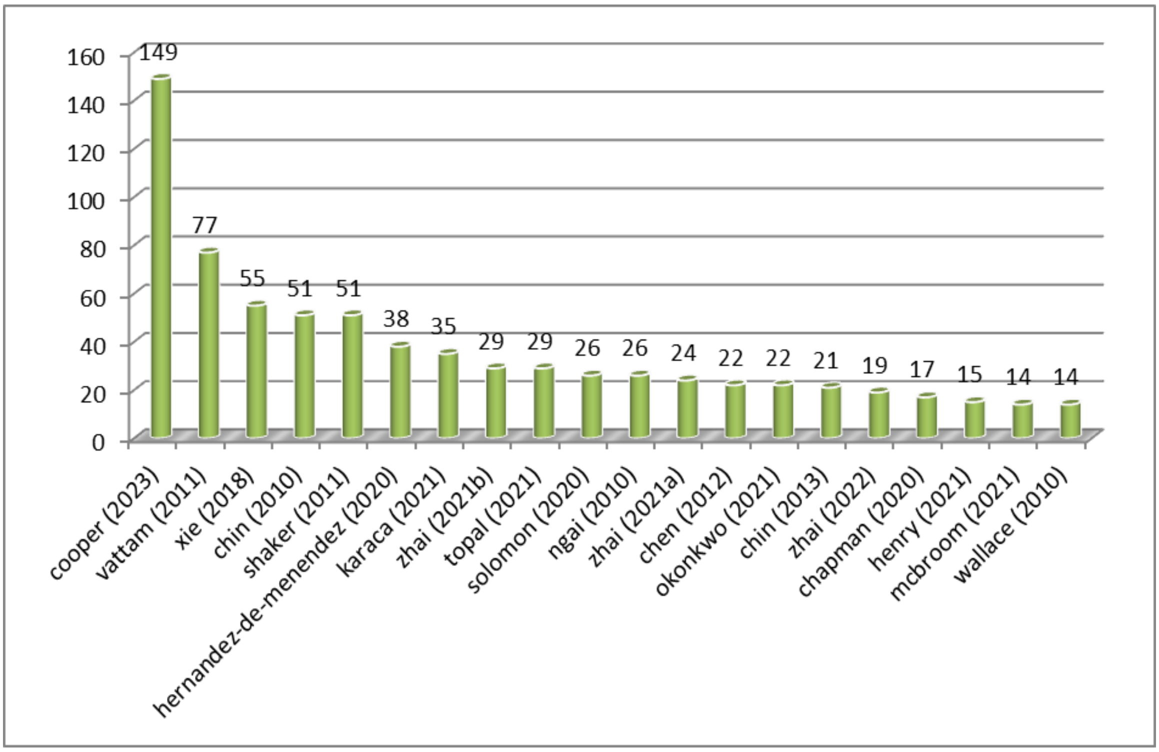

Chart 9. Distribution of Publication Citations on Science Education and Artificial Intelligence

The publication with the highest number of citations in this field focuses on science education and ChatGPT. Developed by OpenAI, ChatGPT has recently become one of the most frequently used applications among AI trends due to its potential educational applications. One of the major advantages of the ChatGPT application is its high capability to adapt to educational contexts. Researchers suggest that appropriate use of this application could lead to significant advancements in distance or online education systems (Bozkurt & Sharma, 2023; Zhai, 2023). This emphasis on the alignment of ChatGPT with educational systems may explain why a publication on ChatGPT receives a high number of citations or references in our current technological era. The second most cited publication is "Understanding Complex Natural Systems by Articulating Structure-Behavior-Function Models," published by Vattam et al. in 2011 in the *Journal of Educational Technology & Society*. This publication investigates the effectiveness of an AI-based interactive learning environment for understanding the structure-behavior-function models of complex systems. The third most referenced publication is "Learning and Teaching Engineering Design through Modeling and Simulation on a CAD Platform," published by Xie et al. in 2018 in *Computer Applications in Engineering Education*. This publication offers a theoretical perspective on the use of modeling and simulation applications on a CAD platform to teach science concepts.

After examining publication-level citations, an analysis of the most cited authors was conducted. The data reveal that the most cited author in this field is Grant Cooper, who is also the author of the publication with the highest number of citations. The author has a total of 149 citations. The top 20 most cited authors are presented in Chart 10.

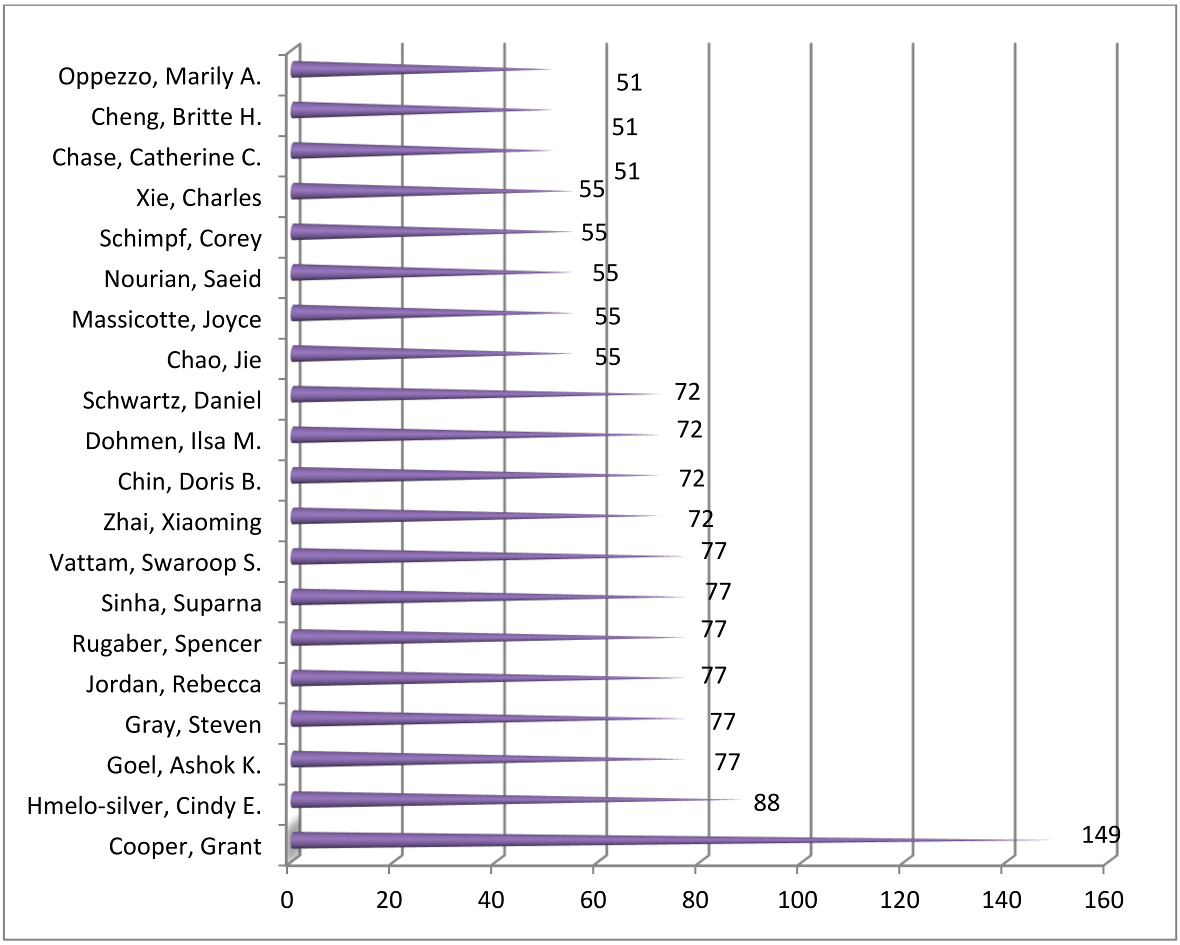

Chart 10. Author Citation Distribution in Science Education and Artificial Intelligence

Analysis of the data reveals that the second most cited author is Cindy E. Hmelo-Silver. Hmelo-Silver is listed among the authors of the second most cited document in the field. She has authored two publications related to science education and artificial intelligence and has a total of 88 citations. She is affiliated with Indiana University Bloomington. Additionally, six researchers with 77 citations each, as shown in Chart 10, are among the authors of the second most cited document. Following the examination of the most cited authors, an analysis of the most cited journals in the field has been conducted. The top 20 most cited journals are presented in Chart 11.

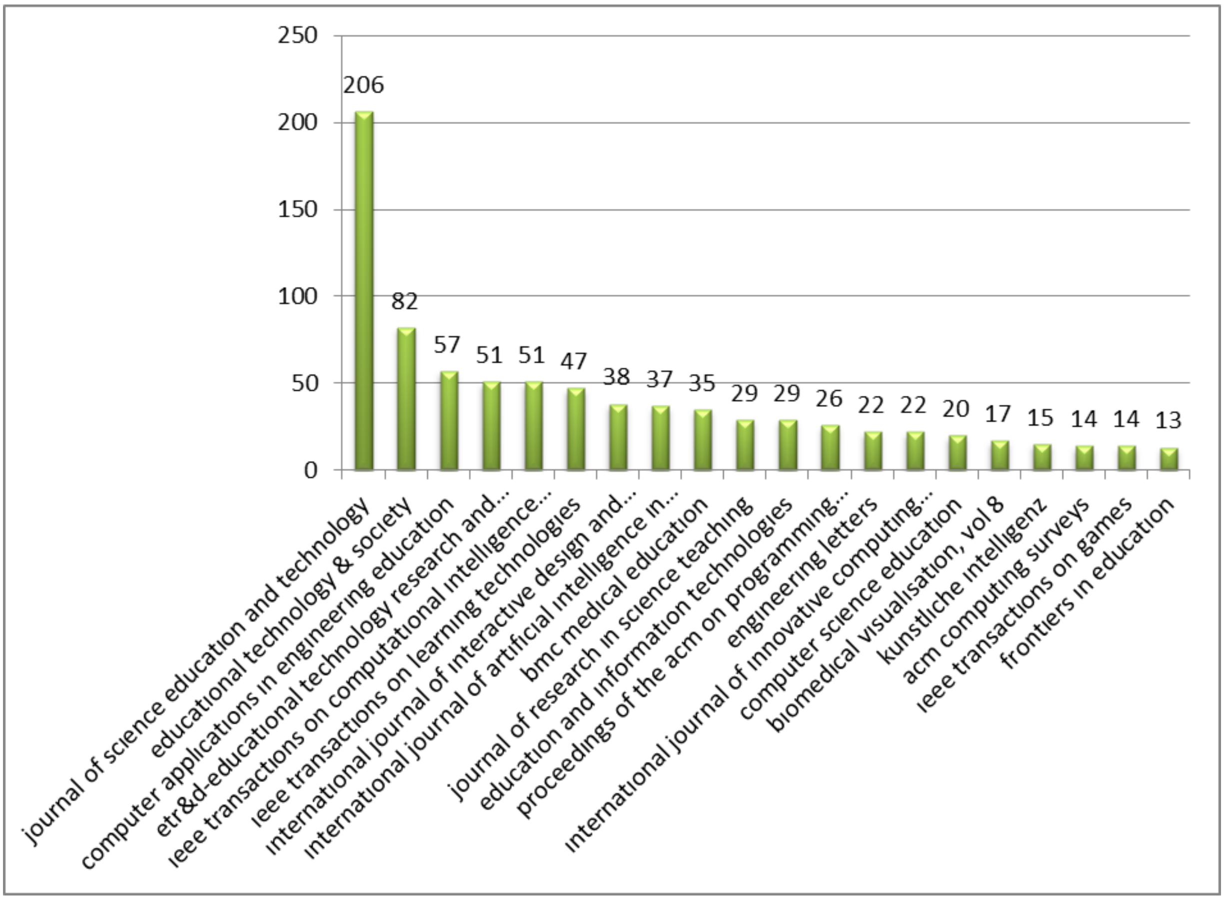

Chart 11. Most Cited Journals and Number of Citations in Science Education and Artificial Intelligence Research

Analysis of citation data reveals that the most cited journal in the field of science education and artificial intelligence is the "Journal of Science Education and Technology," with a total of 206 citations. This journal is also where the most cited article is published and ranks among the top three journals in terms of publication volume in this field. The journal focuses on themes related to science education and technology. The second most cited journal is "Educational Technology & Society," with 82 citations, and it is the publication source for the second most cited article. The third journal in terms of citations is "Computer Applications in Engineering Education," which is the publication source for the third most cited article.

Findings Related to the Distribution of Keywords Used in Scientific Articles on Science Education and Artificial Intelligence

Another data analyzed in the study in order to reveal the bibliometric profile of articles on science education and artificial intelligence are keywords. The analysis identified a total of 364 keywords, each appearing at least once. Among these, 34 keywords appeared two or more times, 12 keywords appeared three or more times, and 7 keywords appeared four or more times. Additionally, 6 keywords appeared five or more times. The top 20 most frequently occurring keywords are presented in Chart 12.

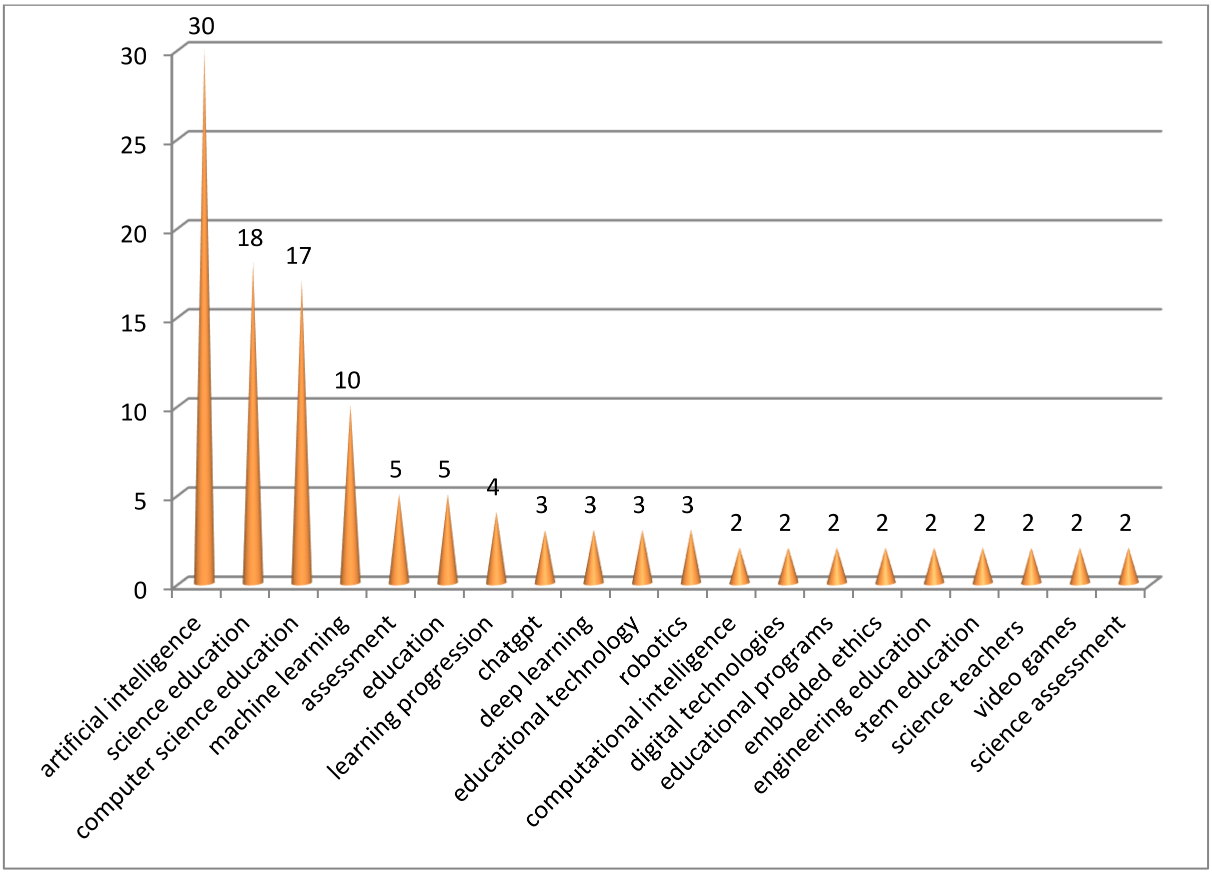

Chart 12. Keywords & Occurrences

The analysis of data reveals that the most frequently used keyword in the 89 articles on artificial intelligence and science education is "artificial intelligence," which appears 30 times. The second most frequently used keyword is "science education," occurring 18 times. The sequence continues with "computer science education" (17 occurrences), "machine learning" (10 occurrences), "assessment" (5 occurrences), and "education" (5 occurrences). Given the focus of this study on articles related to science education and artificial intelligence, it is expected that "artificial intelligence" and "science education" would be the most frequently repeated keywords. Examining the top 20 keywords reveals that references to artificial intelligence in science education are not limited to the concept of technology but also include interdisciplinary approaches such as computer science education, machine learning, engineering education, robotics, video games, digital technologies, and STEM education. The prominence of ChatGPT as a keyword suggests that it is a preferred artificial intelligence application in educational programs and environments. The presence of keywords such as "education," "learning processes," "educational technologies," "educational programs," "science assessment," "evaluation," "computational intelligence," and "deep learning" indicates an examination of the contributions of AI applications to science education.

Another notable keyword is "embedded ethics." The inclusion of this term as a keyword in articles on artificial intelligence and science education may reflect concerns and discussions about integrating ethical considerations into AI applications. The appearance of "embedded ethics" suggests that ethical processes are considered in AI and science education research. The co-occurrence map of keywords used in articles on artificial intelligence and science education is presented in Figure 3.

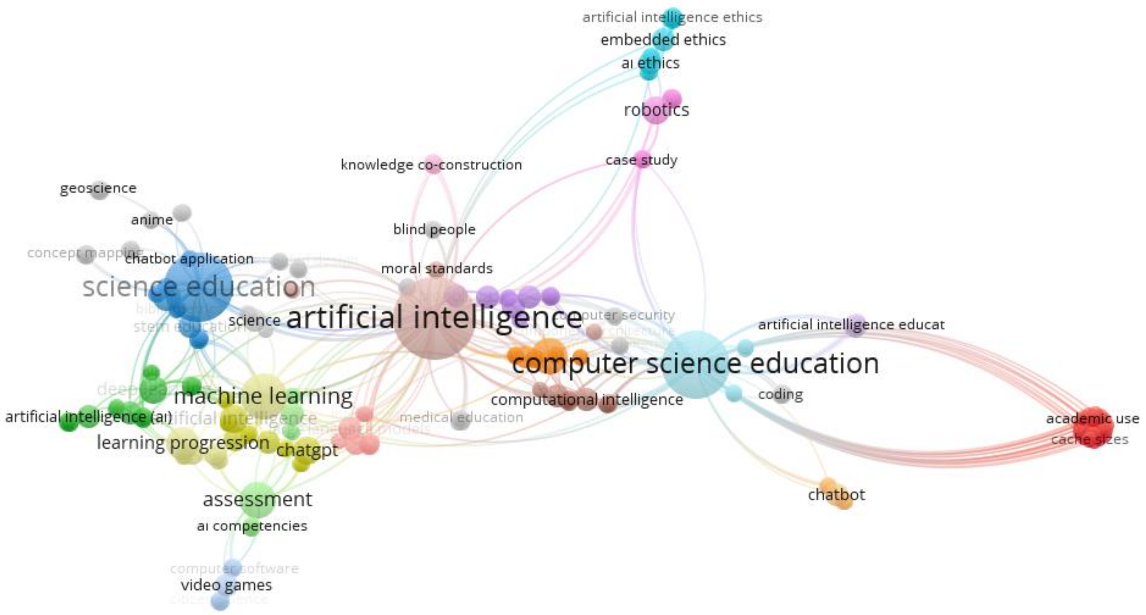

Figure 3. Co-occurrence Map of Keywords in Artificial Intelligence and Science Education Articles

Discussion and Conclusion

This study provides a detailed overview of research trends at the intersection of science education and AI. It examines publication tendencies, language distribution, and major research areas. The study also highlights the most productive journals, institutions, and authors, as well as the most highly cited documents. Additionally, it explores collaboration tendencies, identifying key countries and institutions involved in joint research. These findings offer a comprehensive view of the current research landscape and trends in these fields.

The analysis reveals that the first publication on science education and AI appeared in 1985. Subsequent publication activity was inconsistent, with notable gaps in the 1990s. However, in the early 2000s, research on Technological Pedagogical Content Knowledge (TPACK) gained momentum, sparking significant discussions on integrating technology into education (Lin et al., 2013; Schmid et al., 2024). This period saw an increased emphasis on connectivism and the rapid pace of technological advancements, setting the stage for incorporating AI in educational settings. A marked increase in the number of publications began in 2018, peaking in 2023. The data suggest a renewed interest in the field post-2018, with a sharp rise in publications from 2020 onwards, likely driven by the development and accessibility of AI technologies, particularly chatbots, which have facilitated more research and applications in education (Roll & Wylie, 2016). The surge in publications from 2020 onward highlights the growing interest in AI's role in science education, supported by expanding digital networks and increased collaborative research. The COVID-19 pandemic, which began in late 2019, made it necessary for individuals to become deeply engaged with technology and to accept it, thereby accelerating technological development and accessibility. During this period, the use of AI technology, especially in the medical field, increased AI research efforts (Alhasan & Hasaneen, 2021).

The analysis indicates that the vast majority of publications in science education and AI are in English, accounting for 91.01% of the total. This trend reflects the dominance of English as the lingua franca in academic publishing, facilitating international collaboration and dissemination of research findings (Swales, 1990). The dominance of English, which is seen as the language of science, is also evident in the results of other bibliometric studies (Mongeon & Paul-Hus, 2015). While English predominates, valuable research is also being conducted and published in other languages such as Russian, Spanish, French, Korean, Portuguese, and Ukrainian. This linguistic diversity, though limited, underscores the global interest in the intersection of science education and AI, while also highlighting potential barriers for non-English-speaking researchers in accessing and contributing to the broader academic discourse.

Research areas within publications on science education and AI span 23 different fields, with the majority (49.43%) concentrated in educational research. Educational researchers are continuously exploring new instructional methods and tools to improve teaching practices and enhance student learning outcomes. This pursuit of innovation arises from the understanding that traditional teaching methods may not fully engage students or effectively foster learning. The increasing interest in AI applications in educational research can be attributed to this recognition. This focus on integrating AI into educational practices and studying its impact on learning and teaching is understandable, given the growing interest in leveraging AI technologies to enhance educational outcomes, personalize learning experiences, and improve instructional methods. AI's potential to revolutionize education through adaptive learning systems, intelligent tutoring, and data-driven insights has made it a prominent topic within educational research (Rammer et al., 2022). The recent accessibility and novelty of AI technology have spurred researchers' interest, leading to increased exploration of its applications in education.

Another finding of the research indicates that studies on science education and artificial intelligence are primarily published in educational research and AI application journals. "Frontiers in Education" stands out as the most productive journal in this field, particularly noted for its research-based approaches. This multidisciplinary journal focuses on education for human development, addressing global educational challenges and opportunities. Its high CiteScore, open access and relevance to AI and science education topics make it a popular choice among researchers, explaining its prominent position in our study. The "International Journal of Artificial Intelligence in Education" and the "Journal of Science Education and Technology" are also leading journals in this area. The "International Journal of Artificial Intelligence in Education" has a CiteScore of 11.1, while the "Journal of Science Education and Technology" has a CiteScore of 9.4. Given their focus on technology and AI, it is expected that research in these fields would be published in these journals. They play a crucial role in promoting applied research in AI and educational technologies.

The distribution of productive countries in the field underscores the significant role of the United States, which accounts for 44.94% of the publications. The USA's pioneering role in integrating technological systems with science education, reflected in concepts like "Science-Technology-Society" (STS) and STEM education, reinforces its leading position (Layton, 1971; Ramaley, 2017). Germany ranks second, with 10 publications, due to its strong research infrastructure and focus on STEM education (OECD, 2022). Other notable contributors include Australia, Spain, China, and search in these regions. Leading researchers such as Xiaoming Zhai from the University of Georgia and Kevin C. Haudek from Michigan State University reflect their institutions' prominent roles. The concentration of significant research activity in these regions and institutions underscores their advanced capabilities and collaborative networks.

Grant Cooper's 2023 paper on ChatGPT, with its high citation count, underscores the significant interest in AI tools for educational purposes. This document's prominence highlights the growing importance of ChatGPT in advancing remote and online education. Similarly, Vattam et al.'s (2011) work on AI-based interactive learning environments and Xie et al.'s (2018) study on CAD-based modeling are highly cited. Cindy E. Hmelo-Silver, a notable contributor with 88 citations, and the institutions linked to her research, such as Indiana University Bloomington, demonstrate the substantial impact of specific researchers and their affiliations. The most cited journals, including the Journal of Science Education and Technology, Educational Technology & Society, and Computer Applications in Engineering Education, play crucial roles in disseminating influential research in this field. The analysis of citations reveals that the most cited document is Grant Cooper's 2023 paper in the Journal of Science Education and Technology, with 149 citations. This journal leads in citations with a total of 206 and a 2023 CiteScore of 9.4, indicating its significant impact and relevance. Educational Technology & Society, the second most cited journal, with 82 citations, boasts a CiteScore of 9.1, reflecting its influential role. The third journal, Computer Applications in Engineering Education, where the third most cited document was published, has a CiteScore of 7.2, underscoring its importance in integrating technology into science education. The prominence of these journals, all with high CiteScores, highlights the critical role of educational technology in AI and science education research. This situation can be attributed to the tendency of researchers focusing on AI to first review and cite studies published in these leading journals. Because the journals' strong focus on integrating AI into educational practices aligns with current trends and demands for innovative teaching and learning methods.

Lastly, the bibliometric analysis of keywords from articles on science education and AI reveals several significant insights. The prevalence of "artificial intelligence" and "ChatGPT" underscores the increasing integration and transformative potential of AI technologies in education. The frequent occurrence of interdisciplinary terms such as "computer science education," "machine learning," and "STEM education" indicates a holistic approach to incorporating technological advancements to enhance learning experiences. Ethical considerations, highlighted by the keyword "embedded ethics," emphasize the growing awareness of the need for ethical frameworks in AI applications in education. Ethics in artificial intelligence (AI) is seen as a critical area of focus due to the significant ethical and socio-political challenges that AI presents. That's why, it is said that integrating ethical considerations into AI development is essential to address these challenges and ensure that AI systems align with ethical principles (Coeckelbergh, 2020). The focus on keywords related to learning processes, and educational technologies that emphasise integrated teaching methods such as STEM (Ramaley, 2017), and assessment also underscores AI's potential to improve educational outcomes. These findings suggest future research should further explore ethical implications, interdisciplinary methods, and the role of AI in enhancing assessment processes to maximize its benefits in science education.

To sum up, this comprehensive bibliometric analysis reveals how the fusion of science education and AI mirrors the principles of connectivism, emphasizing the interconnected nature of contemporary learning and technology. The study illustrates how advancements in AI and collaborative research efforts enrich our understanding of science education, reflecting the connectivist idea that learning thrives through the interconnections between various fields and knowledge domains.

Recommendations

This study provides valuable insights into the current research landscape at the intersection of science education and AI. The high impact and academic influence of the leading journals, as indicated by their CiteScores, reflect the growing importance and relevance of AI and educational technology in science education research. Future research should continue to explore the potential of AI to transform educational practices, addressing the challenges and opportunities it presents. By fostering collaboration and leveraging technological advancements, researchers can contribute to the development of innovative, effective educational strategies that meet the needs of learners in an increasingly digital world.

Limitations

This bibliometric analysis has several limitations. Firstly, the study was conducted exclusively using the Web of Science (WoS) database, which means relevant studies from other databases such as Scopus, IEEE Xplore, and Google Scholar were not included, potentially affecting the comprehensiveness of the results. Secondly, the search was performed using the specific keywords "science educat*" and "artific* intelligen*" in the topic title, which might have excluded relevant studies that use different terminologies. Additionally, the analysis only covers studies published up to 2024, excluding 22 relevant studies that were identified but not included in the final dataset.

References

Alhasan, M., & Hasaneen, M. (2021). Digital imaging, technologies and artificial intelligence applications during COVID-19 pandemic. *Computerized Medical Imaging and Graphics*, 91, 101933 - 101933. https://doi.org/10.1016/j.compmedimag.2021.101933

Anderson, T., & Rivera Vargas, P. (2020). A critical look at educational technology from a distance education perspective. *Digital Education Review, 37,* 208-229. https://doi.org/10.1344/der.2020.37.208-229

Borko, H. (1985). Artificial intelligence and expert systems research and their possible impact on information science education. *Education for Information*, *3*(2), 103-114. https://doi.org/10.3233/EFI-1985-3203

Bozkurt, A., & Sharma, R. C. (2023). Challenging the status quo and exploring the new boundaries in the age of algorithms: Reimagining the role of generative AI in distance education and online learning. *Asian Journal of Distance Education, 18*(1), i-viii. https://doi.org/10.5281/zenodo.7755273

Brynjolfsson, E. & Mcafee, A. (2017), Artificial intelligence, for real. *Harvard Business Review*, *1,* 1-31.

Chen, X, Wang, Y, Nakanishi, M, Gao, X, Jung, TP, Gao, S. (2015). High-speed spelling with a noninvasive brain– computer interface. *Proceedings of the National Academy of Sciences*, *112(44),* E6058–E6067. https://doi.org/10.1073/pnas.1508080112

Coeckelbergh, M. (2020). *AI ethics.* MIT Press

Cooper, G. (2023). Examining science education in ChatGPT: An exploratory study of generative artificial intelligence. *Journal of Science Education and Technology*, *32*(3), 444-452. https://doi.org/10.1007/s10956-023-10039-y

Collins, A., & Halverson, R. (2018). *Rethinking education in the age of technology: The digital revolution and schooling in America*. Teachers College Press.

Deveci Topal, A., Dilek Eren, C., & Kolburan Geçer, A. (2021). Chatbot application in a 5th grade science course. *Education and Information Technologies*, *26*(5), 6241-6265. https://doi.org/10.1007/s10639-021-10627-8

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of business research*, *133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

Downes, S. (2007, February 03). What connectivisim is. https://halfanhour.blogspot.com/2007/02/what-connectivism-is.html

Ellegaard, O. (2018). The application of bibliometric analysis: disciplinary and user aspects. *Scientometrics, 116*(1), 181-202. https://doi.org/10.1007/s11192-018-2765-z

Frantz, R. (2003). Herbert Simon. Artificial intelligence as a framework for understanding intuition. *Journal of Economic Psychology, 24*(2), 265-277. https://doi.org/10.1016/S0167-4870(02)00207-6

Good, R. (1987). Artificial intelligence and science education. *Journal of Research in Science Teaching*, *24*(4), 325-342. https://doi.org/10.1002/tea.3660240406

Goodman, D. (2007). Update on scopus and web of science. *The Charleston Advisor*, *8*(3), 15-15.

Grunhut, J., Marques, O., & Wyatt, A. T. M. (2022). Needs, challenges, and applications of artificial intelligence in medical education curriculum. *JMIR Medical Education, 8*(2), e35587. https://doi.org/10.2196/35587

Hamal, O., Faddouli, N. E., Harouni, M. H. A., & Lu, J. (2022). Artificial intelligent in education. *Sustainability, 14*(5), 2862. https://doi.org/10.3390/su14052862

Hawkins, D. T. (2001). Bibliometrics of electronic journals in information science. *Information Research, 7*(1), 7-1.

Hengstler, M., Enkel, E., & Duelli, S. (2016). Applied artificial intelligence and trust—The case of autonomous vehicles and medical assistance devices. *Technological Forecasting and Social Change*, *105*, 105-120. https://doi.org/10.1016/j.techfore.2015.12.014

Hrastinski, S. (2019). What Do We mean by blended learning?. *TechTrends 63,* 564–569. https://doi.org/10.1007/s11528-019-00375-5

Huang, L. (2023). Ethics of artificial intelligence in education: student privacy and data protection. *Science Insights Education Frontiers, 16*(2), 2577-2587. https://doi.org/10.15354/sief.23.re202

Hurd, J. M. (1988). Artificial-intelligence-a challenge for information-science education. *Bulletin of the American Society for Information Science*, *14*(6), 21-22.

Kamalov, F., Santandreu Calonge, D., & Gurrib, I. (2023). New era of artificial intelligence in education: Towards a sustainable multifaceted revolution. *Sustainability*, *15*(16), 12451. https://doi.org/10.3390/su151612451

Kaur, M. (2013). Blended learning-its challenges and future. *Procedia-social and behavioral sciences*, *93*, 612-617. https://doi.org/10.1016/j.sbspro.2013.09.248

Larsson, S. (2020). On the governance of artificial intelligence through ethics guidelines. *Asian Journal of Law and Society*, *7*(3), 437-451. https://doi.org/10.1017/als.2020.19

Layton, E. (1971). Mirror-image twins: the communities of science and technology in 19th-century america. *Technology and Culture*, 12, 562 - 580. https://doi.org/10.2307/3102571

Leyva, E., Walkington, C., Perera, H. N., & Bernacki, M. L. (2022). Making mathematics relevant: an examination of student interest in mathematics, interest in stem careers, and perceived relevance. *International Journal of Research in Undergraduate Mathematics Education, 8*(3), 612-641. https://doi.org/10.1007/s40753-021-00159-4

Lin, T. C., Tsai, C. C., Chai, C. S., & Lee, M. H. (2013). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*, 325-336.

Mavroudi, A., Giannakos, M., & Krogstie, J. (2017). Supporting adaptive learning pathways through the use of learning analytics: developments, challenges and future opportunities. *Interactive Learning Environments, 26*(2), 206–220. https://doi.org/10.1080/10494820.2017.1292531

Miller, R. K. (2017). Building on Math and Science: The New Essential Skills for the 21st-Century Engineer: Solving the problems of the 21st century will require that engineers have a new set of skills and mindsets. *Research-Technology Management, 60*(1), 53–56. https://doi.org/10.1080/08956308.2017.1255058

Minsky, M. (1974). *Artificial Intelligence*. https://home.mis.u-picardie.fr/~furst/docs/Minsky_Frames_1974.pdf

Mongeon, P., & Paul-Hus, A. (2015). The journal coverage of Web of Science and Scopus: a comparative analysis. *Scientometrics*, 106, 213 - 228. https://doi.org/10.1007/s11192-015-1765-5.

Nagaraj, B. K., Kalaivani, A., Begum, S., Akila, S., & Sachdev, H. K. (2023). The emerging role of artificial intelligence in stem higher education: A critical review. *International Research Journal of Multidisciplinary Technovation*, *5*(5), 1-19. https://doi.org/10.54392/irjmt2351.

OECD, (2022). *Reviews of Innovation Policy Germany-Building Agility for Successful Transitions.* https://www.oecd.org/content/dam/oecd/en/publications/reports/2022/10/oecd-reviews-of-innovation-policy-germany-2022_34a18c3c/50b32331-en.pdf

Pei, B., Xing, W., & Wang, M. (2021). Academic development of multimodal learning analytics: A bibliometric analysis. *Interactive Learning Environments,* 1–19. https://doi.org/10.1080/10494820.2021.1936075

Prahani, B. K., Rizki, I. A., Suprapto, N., Irwanto, I., & Kurtuluş, M. A. (2024). Mapping research on scientific creativity: A bibliometric review of the literature in the last 20 years. *Thinking Skills and Creativity*, *52*, 101495. https://doi.org/10.1016/j.tsc.2024.101495

Pratama, M. P., Sampelolo, R., & Lura, H. (2023). Revolutionizing education: harnessing the power of artificial intelligence for personalized learning. *Klasikal: Journal of Education, Language Teaching and Science, 5*(2), 350-357.

Rammer, C., Fernández, G. P., & Czarnitzki, D. (2022). Artificial intelligence and industrial innovation: Evidence from German firm-level data. *Research Policy, 51*(7), 104555. https://doi.org/10.1016/j.respol.2022.104555

Ramaley, J. A. (2017). *Communicating and Collaborating Across Diciplines. Accelerating Systemic Change in STEM Higher Education*. https://ascnhighered.org/ASCN/posts/192300.html

Roll, I., & Wylie, R. (2016). Evolution and revolution in artificial intelligence in education. *International Journal of Artificial Intelligence in Education*, *26*, 582-599. https://doi.org/10.1007/s40593-016-0110-3

Rumelhart, D. E., Hinton, G. E., & Williams, R. J. (1985). Learning internal representations by error propagation. In D. E. Rumelhart & J. L. McClelland (Eds.), *Parallel distributed processing:*

Explorations in the microstructure of cognition (pp. 318-362). MIT Press. https://www.cs.cmu.edu/~bhiksha/courses/deeplearning/Fall.2016/pdfs/Chap8_PDP86.pdf

Schmid, M., Brianza, E., Mok, S. Y., & Petko, D. (2024). Running in circles: A systematic review of reviews on technological pedagogical content knowledge (TPACK). *Computers & Education*, 105024. https://doi.org/10.1016/j.compedu.2024.105024

Shin, D., Kim, H., Lee, J. H., & Yang, H. (2021). Exploring the use of an artificial intelligence chatbot as second language conversation partners. *Korean journal of English language and linguistics*, *21*, 375-391.

Siemens, G. (2005). Connectivism: A learning theory for the digital age. elearnspace. *International Journal of Instructional Technology and Distance Learning, 2*(1), 3–10.

Siedlecki, S. L. (2020). Understanding descriptive research designs and methods. *Clinical Nurse Specialist*, *34*(1), 8-12. https://doi.org/10.1097/NUR.0000000000000493

Sinkovics, N. (2016). Enhancing the foundations for theorising through bibliometric mapping. *International Marketing Review*, *33*(3), 327-350.

Spiess, T., Salcher, F., & Dilger, T. (2021). The reality of artificial intelligence: Social learning theory, connectivism, and human standards in learning versus machine learning. *EDULEARN21 Proceedings*, 2080-2088. https://doi.org/10.21125/edulearn.2021.0473

Swales, J. M. (1990). *Genre analysis*. Cambridge University Press.

Tapalova, O., & Zhiyenbayeva, N. (2022). Artificial intelligence in education: AIEd for personalised learning pathways. *Electronic Journal of e-Learning*, *20*(5), 639-653.

Turing, A. M. (1950). Computing machinery and intelligence. In B. J. Copeland (Ed.), *The essential Turing* (pp. 443-464). Clarendon Press.

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences*, *15*(3), 398-405. https://doi.org/10.1111/nhs.12048

Van Eck, N. J., & Waltman, L. (2009). How to normalize cooccurrence data? An analysis of some well-known similarity measures. *Journal of the American Society for Information Science and Technology, 60*(8), 1635-1651. https://doi.org/110.1002/asi.21075

Van Eck, N. J., & Waltman, L. (2014). Visualizing bibliometric networks. Measuring scholarly impact: Methods and practice, 285-320. https://doi.org/10.1007/978-3-319-10377-8_13

Van Eck, N. J., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics, 111,* 1053-1070. https://doi.org/10.1007/s11192-017-2300-7

Vattam, S. S., Goel, A. K., Rugaber, S., Hmelo-Silver, C. E., Jordan, R., Gray, S., & Sinha, S. (2011). Understanding complex natural systems by articulating structure-behavior-function models. *Journal of Educational Technology & Society*, *14*(1), 66-81.

Xie, C., Schimpf, C., Chao, J., Nourian, S., & Massicotte, J. (2018). Learning and teaching engineering design through modeling and simulation on a CAD platform. *Computer Applications in Engineering Education*, *26*(4), 824-840. https://doi.org/10.1002/cae.21920

Yang, Q. F., Lian, L. W., & Zhao, J. H. (2023). Developing a gamified artificial intelligence educational robot to promote learning effectiveness and behavior in laboratory safety courses for undergraduate students. *International Journal of Educational Technology in Higher Education*, (*20*)18, 2-31. https://doi.org/10.1186/s41239-023-00391-9

Zhai, X. (2023). ChatGPT for next generation science learning. *XRDS: Crossroads, The ACM Magazine for Students*, *29*(3), 42-46. https://doi.org/10.1145/3589649

Zyoud, S. E. H., Waring, W. S., Al-Jabi, S. W., & Sweileh, W. M. (2017). Global cocaine intoxication research trends during 1975–2015: A bibliometric analysis of Web of Science publications. *Substance Abuse Treatment, Prevention, and Policy*, *12*, 1-15. https://doi.org/10.1186/s13011-017-0090-9

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Applying Technology and Awareness Integration Theory for Quality Early Childhood Care and Education

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Abstract

Administrators from 10 early childhood care and education (ECCE) programs in a Pacific Southwestern state in the United States participated as one part of a qualitative longitudinal study exploring the use of technology at the onset of COVID-19 in March 2020 through May 2023. The purpose of this basic qualitative study was to explore how ECCE program administrators employed technologies to support staff, children, and families while providing continuity of quality in curriculum, pedagogy, professional development, parent engagement opportunities, and community outreach during and following the Pandemic. Findings revealed that diverse technologies were used, offered, and supported by ECCE program administrators. Administrators acknowledged that continued use of technologies contributed to and sustained overall program quality; supported children's attainment of developmental milestones; and enhanced parent and staff relationships, capacity building, and engagement. Further, this paper reports on ways ECCE program administrators adapted findings from the study to foster inclusion of awareness integration theory into their daily practices. Consistency of quality care and education has promoted children's development in all learning domains leading to their formal school readiness. Examples of technology as a post-pandemic contributor to quality in ECCE programs are shared.

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Introduction

With the onset of the COVID-19 Pandemic, every aspect of the early childhood field involving children from birth to age eight and their families, and those who provided care and education for them, was dramatically impacted (Jalongo, 2022). A Pandemic is described as outbreaks that cause high-spread sickness that interrupt the economy and cause deaths (Akin & Gözel, 2020). As the Pandemic reached the United States, administrators of early childhood care and education (ECCE) programs were thrust into solving novel problems with lacking information, resources, or support from agencies (Kirby et al., 2021; Logan et al., 2021). ECCE administrators at every level of programming for young children, honed their leadership skills to create and maintain quality environments for children, where they felt safe and respected, and were motivated to learn (Movahedazarhouligh & Jones, 2024). ECCE programs across the globe were challenged to suddenly provide safe and responsive programming to address children's developmental milestones -- physical, cognitive, social, and emotional -- in a virtual learning environment (see Yildiz et al., 2022), or in a program that served the children of first responders to the Pandemic (Jalongo, 2022).

The roles and responsibilities of ECCE administrators during the Pandemic were continually changing as they respond to environmental and other external factors (Kirby et al., 2021; Logan et al., 2021). Administrators and directors in childcare programs used leadership skills that were adaptive and based on strengths (Movahedazarhouligh & Jones, 2024). As instructional leaders in ECCE, administrators' goals were to provide continuity of quality care and education by continuing to offer developmentally appropriate practices (DAP) in the virtual learning environment or in centers despite having to follow restrictive health and safety protocols (Jalongo, 2022). ECCE programs continued to address standards for optimal learning and development for young children.

During the COVID-19 Pandemic, ECCE administrators in the role of program directors kept their centers open for first responder parents, which added to their financial burden (Manoukian, 2022). As was faced in many countries around the globe, ECCE administrators faced financial challenges due to parental discord regarding tuition payments, as well as purchasing resources for online education, providing professional development to use the needed technology, and coordinating virtual learning opportunities for children and families (Yildiz et al., 2022). Moreover, findings from one study conducted in the United States during the pandemic revealed that public school principals believed their future roles would shift from being an instructional leader to focusing primarily on safety and security issues, supporting the wellbeing and mental health of teachers and students, and increasing family engagement (Reid, 2021), which calls for adaptive leadership. ECCE administrators demonstrated adaptive leadership as they prepared for change and adapted to the problems inherent in addressing the challenges of the Pandemic (Bagwell, 2020; Tollman et al., 2021).

Administrators of ECCE programs are essential educators in helping children meet their developmental milestones and acquire the formal school readiness skills they need to be successful (Cadima et al., 2015; Downer et al., 2016; Pianta et al., 2017). With the Pandemic, the importance and fluid roles of ECCE administrators were heightened, and new responsibilities were added for administrators as programs move into leading their teachers and staff into virtual environments (Stone-Johnson & Miles Weiner, 2020) and increasing their mentoring, coaching, and social responsibilities due to the Pandemic. Barriers and restrictions were placed on ECCE programs operating as part of a school or an independent for profit or not-for-profit agency, or private program. During and following the COVID-19 pandemic and its variants, researchers of this study set out to explore how administrators of ECCE programs, who supported the transition to the virtual learning and/or kept their programs open, view technology as a post-pandemic contributor to program quality.

Review of the Literature

Virtual learning environments have become one of the current avenues adopted by ECCE programs throughout the Pacific Southwestern United States. ECCE programs operate as part of school districts, agencies, organizations, and private or independent programs (Johnson et al., 2022). At the outset of the Pandemic, facilitating virtual learning environments for ECCE classes and sessions was a major concern for administrators (Kaimara et al., 2022). As programs scrambled to offer online services for children and families, The American Academy of Pediatrics issued a statement that preschool level children should only be exposed to a maximum of one hour of screen time per day (Yildiz & Songul Yalcin, 2024); therefore, among other issues considered by administrators, children's exposure to screen time had to be considered (Yildiz & Songul Yalcin, 2024). Facilitating teachers' and staffs' abilities to address all aspects of children's development within the limited time frame allowed for children's learning in a virtual environment was challenging (Kaimara et al., 2022).

The virtual environment demonstrated a way of learning that did not require children to be physically present in the ECCE center and provided essential learning alternatives and opportunities. Over time, administrators found that learning in a virtual environment allowed for flexibility and effectiveness (see Hamutoglu et al., 2020; Naimi-Akbar et al., 2023). As teachers, children, parents and guardians became acclimated to technology and the scheduled activities they found the flexibility of virtual learning environments provided opportunities for teaching and learning in various ways (Hamutoglu et al., 2020). Administrators embraced virtual learning environments as an alternative to face-to-face teaching and learning, for teachers' staff development and mentoring, parent engagement and education, and community outreach. Administrators recognized that the new opportunities provided avenues for professional development as viable options for program continuity. Administrators, teachers, and researchers in this study established the understanding that virtual environments provide opportunities for ongoing development and learning, family engagement, and community outreach.

Several indispensable factors influence virtual learning: the students -- the prior skills of teachers before entering the virtual environment, the technology available, and the supporting software and devices available (Rayuwati, 2020). Furthermore, collaboration with others and development of resources and materials allow for successful learning of all stakeholders in virtual environments (Rayuwati, 2020). Within a successful virtual environment, the development of children is prioritized, which in turn, makes whole child development and learning important.

Whole Child Development & Learning

Following the move to virtual learning environments, an emphasis was placed on supporting children's learning in all developmental domains. The whole child developmental approach involves valuing children's physical development and emotional state (Cantor et al., 2021). It includes social skills such as building relationships that directly influence their learning (Manoukian, Researchers in the UK found that children's attendance in early childhood programs were positively associated with communication and problem-solving skills, and personal-social development. Children who participated in ECCE programs during the pandemic had learning benefits (Davies, 2023). The development of children is an important aspect of success in their education (Kriener-Althen et al., 2020). In the ECCE classroom, a child's development is measured to determine their learning and growth (Kriener-Althen et al., 2020). Cognitive, physical, social, emotional, and technological development and learning were addressed when working with children and families in the virtual environment created by the ECCE program.

Physical Development

Physical development is a domain that teachers addressed during virtual learning; however, researchers suggested that addressing the physical developmental domain was an issue (Daum et al., 2021). Teachers worked to strengthen relationships with adults in children's families to suggest ways to support children's physical activities while engaging in the virtual environment (Septian & Sukarmin, 2020). The entire community worked to support children's physical activity in the virtual learning environments by teachers collaborating with the students and family members to intentionally promote physical development (Daum et al., 2021). In the virtual environment, teachers had to be creative in implementing activities for young children to meet the physical standards of their education (Septian & Sukarmin, 2020).

Cognitive Development

Cognitive competence is addressed in virtual learning environments when it is addressed as both knowledge and skills (Kassymova et al., 2021). Cognitive development is connected with building relationships within the virtual environment because researchers found it expands the learning process through collaborative learning (Annansingh, 2019; Kassymova et al., 2021). Cognitively active learning included children's engagement in the class activities and depends on how the teacher facilitates learning to meet the needs of the learners.

Cognitive development includes language skills that are attained at an early age and correlate with children's literacy, pre-reading, and reading competencies and educational successes (Hansen & Broekhuizen, 2021). Researchers explained that language development in virtual learning environments needs interaction with peers and teachers through continuous interactions among children and teachers (Karatas & Tuncer, 2020; Marcum & Kim, 2020). Communication and collaboration are successful in classrooms for young children to increase language skills (Hazaymeh. 2021).

Researchers suggested that incorporating science, technology, engineering, arts, and mathematics (STEAM) in virtual learning environments requires children to be hands-on learners (Chen & Huang, 2023). STEAM components assist in learning success through their learning styles and processing the information provided. Researchers suggested that STEAM in the virtual learning environment is often initiated through games, requiring teamwork and interaction to be successful (Kummanee et al., 2020).

Social-Emotional Development

Social emotional development is an essential area of knowledge and skills that are essential to children's optimum growth and development (Chen & Brotherson, 2022; Peras & Prudente, 2021). For social-emotional learning (SEL) to occur, researchers found that children need to share their emotions with others in the virtual environment because this type of interaction assists in developing cognition skills (Peras & Prudente, 2021). SEL is also essential in developing resiliency in young children (Peras & Prudente, 2021). Challenges to SEL in the virtual environment were found to be a result of low levels of interactions with peers (Champeaux et al., 2022). Other researchers suggested that a social presence is needed in a virtual environment to have positive influence on children's behavior and SEL (Chiu et al., 2021).

Researchers also investigated how children's mental health was affected in the virtual learning environment (Di Malta et al., 2022; Lister et al, 2021; Wang et al., 2022). The importance of more interactions to connect with peers is essential for optimum mental health and wellbeing of children (Di Malta et al., 2022; Samuel et al., 2022). Researchers suggested that the use of technology is not a major factor in the diminished mental health of students, but the lack of interactions and positive relationships had a negative influence (Samuel et al., 2022). Researchers suggested more research is needed in the area of children's wellbeing and mental health in the virtual learning environment (Samuel et al., 2022), children's motivation to learn in the virtual learning environment (Rakow et al., 2023), and development of resiliency (Peras & Prudente, 2021).

Successes and Challenges

Researchers have revealed that virtual learning environments present opportunities for both successes and challenges in meeting young children's developmental domains, particularly in addressing children's social and emotional development (Majadly et al., 2024). Researchers in this study explored administrators' perspectives of the influence of technology on virtual learning environments during and following the Pandemic. Researchers purpose was to gain greater awareness and understanding about how administrators support and successfully navigate virtual learning environments as they provide continuity of quality in ECCE programs.

Virtual Learning Tools

A variety of tools are used in the virtual learning environment to enhance the learning processes for children. Some tools increase children's interactions and collaboration with peers (Sodhar et al., 2020). Google Classroom and Zoom have assisted children's attainment of developmental milestones in the virtual learning environment (Bilal et al., 2022). Another tool utilized was YouTube videos and stories for teaching to heighten children's understanding of learning in the virtual environment (Suryatini, 2022).

Conceptual Framework

Restrictions were placed on ECCE programs operating as part of a school or an independent for profit or not-for-profit agencies, or private programs. During and following the COVID-19 pandemic and its variants, researchers of this study set out to explore how administrators of ECCE programs supported the transition to virtual learning and children's school readiness. The conceptual framework for this study is a combination of the Collaborative framework for Academic, Social, and Emotional Learning (CASEL) and the International Society for Technology in Education (ISTE) standards. The CASEL concepts related to SEL focus on teacher capacity in the following areas: developing student SEL, forming and maintaining positive relationships with students, and developing SEL classroom environments. CASEL includes five competency areas that teachers use to support student's SEL. Those competencies are "self-awareness, self-management, social awareness, relationship skills, and responsible decision-making" (CASEL, n.d., para 3). The ISTE emphasizes standards within the virtual environment to help students become well-rounded contributors while using technology (Crompton, 2023). The ISTE incorporates the following standards for student success: empowered learner, global collaborator, digital citizen, knowledge contributor, innovative designer, and computational thinker. The conceptual framework combines the CASEL framework and the ISTE standards. The CASEL framework is a theory of action. The ISTE is a group of standards that assist in supporting teachers with helping their students be successful in the virtual environment by effectively integrating technology (Crompton, 2023).

CASEL Framework

The theory behind CASEL assists in the development of children's involvement in a community (CASEL, 2013). CASEL's theory of action supports professional development of adults actively involved in the education of children. CASEL has developed standards that assist ECCE administrators, teachers, students and parents in establishing virtual learning environments that supports SEL. The components include self-awareness, self-management, social awareness, relationship skills, and responsible decision making.

ISTE Standards

ISTE represents a group of standards that assist administrators and teachers in promoting learning that empowers children to be successful in the virtual environment (Crompton, 2023). ISTE standards allow for the expansion of resources that help administrators influence the curriculum, pedagogy, and resources to support teachers, families, and young students in the virtual environment. These standards are designed to help students develop their SEL experiences through collaborating and sharing with their peers. The ISTE focuses on seven standards that allow students to be successful in a virtual environment. These standards assist in developing the skills and temperaments students will need in the evolving world (Chang, 2022). The standards consist of empowered learners, making them digital citizens and knowledge constructors, innovative designers, computational thinkers, creative communicators, and global collaborators (Chang., 2022).

Method

ECCE administrators from a Pacific Southwestern state in the United States were recruited in the winter and spring of 2024. The pool of potential participants was obtained from ECCE teachers who volunteered for a longitudinal study that was conducted from the mid-2020s to mid-2023. Administrators were from private and public preschools, agency and religious affiliated preschool programs, and infant-toddler programs in hospitals or university lab schools. Emails were sent to administrators, inviting their participation in the study, who were given the title of principal, director, or coordinator. The email also included information about the intent of the study and volunteer/participant rights. Administrators from 10 early childhood care and education (ECCE) programs consented to participated in a qualitative study exploring their perceptions of their roles in supporting the use of technology at the onset of COVID-19 in January 2020 through May 2023. The study aimed to learn how ECCE program administrators supported their staff in providing continuity of quality ECCE programing in program curriculum, pedagogy, professional development, parent involvement, and community outreach. Administrators of ECCE programs are essential educators in helping their children meet their developmental milestones and acquire the formal school readiness skills they need (Cadima et al., 2015; Downer et al., 2016; Pianta et al., 2017) in virtual environments.

Data Collection & Analysis

Researchers developed a data collection instrument based on the conceptual framework and relevant literature. Interview questions and prompts were reviewed by an expert panel to ensure clarity and ease of understanding for participants. Data was collected via audio recording in Zoom or telephone interviews. Data were analyzed following a six-step process for thematic analysis by Braun and Clarke (2017) and coding processes outlined by Saldaña's (2016). Phase 1 of the analysis was to become familiar with data. At this point, recordings and transcripts of the interviews were reviewed. Phase 2 of the analysis focused on using a priori and open codes to organize the data into initial codes (see Saldaña, 2016). Coding is the process of identifying pieces of data that are of interest to the researcher and were relevant to the phenomenon under study (Braun & Clarke., 2017). Using the conceptual framework as a guide, priori coding, coding data segments that were relevant were used. Structural, descriptive, and axial coding were used to reveal patterns and categories with emerging themes. Data were analyzed by following an inductive process.

Results

Current ECCE administrators who had a minimum of three years of experience as a principal, director, or manager at the onset of the COVID-19 Pandemic responded to one research question: How did the transition to a virtual learning environment and the use of technology influence your programs curriculum, pedagogy, professional development, teacher and parent relationships, and community outreach. The following are representative statements from administrator participants.

Participant 1

After the United States was introduced to COVID-19, early childhood facilities began integrating technology in unprecedented ways. This move to reliance on technology has continued today. It is now part of providing for a safe environment; our curriculum and pedagogy; and the modes of communication and interactions with others in a learning environment. Technology has also changed the way we are doing business today. For instance, to reduce the number and closeness of face-to-face interactions in childcare facilities, some programs started using online payment options instead of accepting payments at the centers, checking their children in and out via an application on their phones, or scanning a QR code as they enter or exit the building.

Participant 2

Crucial skills were missed while children were home with parents, older siblings, or other family members when childcare centers were shut down during the early onset of COVID-19. Opportunities to develop fine motor skills through completing puzzles, lacing cards with strings, pounding play dough, and cutting with scissors were often missed daily. We did what we could to involve children and their families on Zoom, however, because of the ages of the children it was difficult to keep them engaged when parents were not online and participating with the children or acting as co-teachers. When children returned to classrooms early childcare providers had to be innovative because children lacked basic skills, that we had taken for granted.

Participant 3

One use of technology that has continued to the current time is accessing virtual field trips. These became more popular so children could still have learning experiences and exposure without leaving their educational space.

Participant 4

Early childhood classrooms were conducted online during the COVID-19 isolation period. Serving an economically underprivileged area, we had to create an online environment for children closest to a face-to-face classroom. We were aware that building relationships was important for the wellbeing of children and their parents. We would allow children to stay on Zoom and play with each other after classroom hours were over. They were able to have conversations and share their emotions with their friends.

Participant 5

What I have changed after the isolation period during the COVID-19 outbreak in 2020 is making myself available to parents by using technology, which has contributed to strengthening our relationships. I have also started seeking professional development using virtual consulting and classrooms. I use WhatsApp, text, and Zoom to contact parents, inform them about their children, and conduct meetings. I started giving parents access to the camera in my daycare so they could check on their children. I have noticed that parents tend to be more overprotective of their children in the last 4 years after the COVID-19 outbreak. I am extremely aware that children need more assistance with their social-emotional development. They need specific activities and tools to help them develop self-confidence, emotional regulation, and self-esteem. We use CASEL, but I have been learning and implementing the Awareness Integration Theory with the children in my care and their parents and have seen great results.

Participant 6

When the COVID-19 outbreak happened, all early childhood education establishments faced a major challenge in providing the same quality of care virtually – but we gave it our best effort. Young children did not have the skills or capabilities to use virtual technology, and teachers needed professional development, coaching, and mentoring. Parents also needed coaching and mentoring. The main concern expressed by the staff was children’s lack of social-emotional skills. I believe that the isolation period caused major delays in children's physical, language, and social-emotional development.

Participant 7

Most children who were born during the COVID-19 isolation period were lacking skills in all developmental domains. This was so much that some children’s behavior resembled the behaviors of children with disabilities, including autism. I started using technology not only to keep my connection with children and their parents but also for the professional development of my staff members. Technology is still used for much of the professional development I offer my staff. I want them to understand and use follow CASEL and include ISTE standards for students.

Participant 8

An option for parents, that teachers typically like best, is providing the option for parents to see their child via cameras in the classroom instead of visiting the classrooms in person. Cameras are used for security as well as observation of staff and children. As far as children using technology in the classroom, It is important for children to be introduced to using tablets – they are a big part of the way kindergarteners are taught and tested.

Participant 9

Teachers began utilizing digital websites for online learning and for in the classroom instruction. Children as young as three years old started using a mouse and their pointer fingers to maneuver around on the web. Although screentime is limited, these innovations have continued to the present day. To have a quality program that prepares children for formal school, I need to be attentive to the needs of my staff in preparing children to learn in new ways – many of those new ways involve technology. While I prefer holding a book and turning pages, I can still see the value of having authors of children's books read their stories on U-TUBE and illustrators describe how they create art for their books.

Participant 10

I have used several apps, such as Zoom, to conduct parenting classes, parent-teacher meetings, staff meetings and trainings, and classes for children. We use play-based practices, DAP, and standards for best practices in our program. The most beneficial and effective method I have used to help children and their parents develop social-emotional competency, self-esteem, self-efficacy, self-confidence, and emotional regulation is the Awareness Integration Theory. I attended training on AIT have used this theory in person, virtually, and through the AIT app. AIT offers a process to follow step by step. It also aligns with program values and positive outcomes for children who attend my program.

Findings from this research revealed that overtime, administrators supported the use a diverse array of technologies for multiple uses in ECCE programs for children from birth to entry into formal school. Administrators acknowledged that continued use of technology has the potential to contribute to overall program quality. Examples include the role of technology to embed awareness integration theory into practice. As an initial adaptation from face-to-face teaching and learning to the virtual environment, administrators in this study suggested adding a "technological" domain of learning to the list of children's developmental domains because ECCE programs are key to children's learning and readiness for formal schooling. Themes that emerged from the data indicate that administrators in this study facilitated the use of technologies for: (1) building and center security and safety; (2) parent and family communication, education, and co-teaching; (3) curriculum and pedagogy to meet children's developmental domains of learning – physical, cognitive, social, emotional, and technological; (4) assessment of child health, wellbeing, and progress toward meeting developmental milestones; (5) professional learning opportunities for staff; and (6) licensing requirements for program quality.

Discussion

Virtual learning in ECCE is a form of education that combines curriculum, pedagogy, learning materials, and the use of technology that supports interaction between administrators, teachers, children, and parents. Virtual learning complements the face-to-face classroom environment in implementing educational standards, best practices, and innovative programs. Administrators are influential in encouraging teachers and families to incorporate instructional methods that promote children's developmental domains and support children meeting their developmental milestones and achieve readiness for formal schooling. Some participants recognized AIT in both the online learning and face-to-face environments. Findings revealed that the strategies and practices addressed in the research should be utilized by teachers in working with children and families (Kamei et al., 2021). Findings also deem administrators' roles in encouraging teachers to address children's developmental domains in virtual learning environments is important. Relationships among the administrators, teachers, and families are needed to maintain a learning environment in an online teaching environment, which is confirmed in the literature (Mahmud, 2022). Researchers explained that more studies are needed to investigate the importance of addressing children's developmental domains in virtual learning environments (Veraksa et al., 2021). The findings of this study may potentially enlighten others about the problems and successes found in remote and virtual learning environments with early childhood students. The potential positive change may be using participants' responses to identify possible training and professional learning opportunities that would lead to adjustments in virtual learning environments to promote whole child development with an emphasis on social-emotional development in early childhood students.

Conclusion

With this understanding of the influential role of virtual learning on the educational environment for students also came an increased interest in knowing and understanding how students' social and emotional developmental domains are being addressed in virtual environments (Wang, 2022). A significant increase in social and emotional maladjustment in young children who lack prosocial behaviors and have high incidents of conduct problems appears to be an outcome of the Pandemic (Jung & Barnett, 2021). Social emotional learning became an area that gained the attention of ECE professionals who recognized these domains of learning needed to be addressed in the virtual environment. Insufficient research had been conducted to provide the ECCE community evidence-based information about students' social-emotional growth and areas of wellbeing and mental health while learning in virtual environments. Social and emotional development lays a foundation for future academic success (Panayiotou et al., 2019). Clarification is needed on how young students' social and emotional development was influenced in virtual learning environments. Although researchers have investigated this issue, the topic has yet to be explored thoroughly. Little research is reported in the current literature on ECE teachers' experiences on the influence of virtual learning environments on students' social emotional development.

Recommendations

Participants in this study focused on children's developmental domains and emphasized the importance of children's social emotional learning. Some administrators embedded Awareness Integration Theory into their consistent practice to support staff, children, and their families. Understanding administrators' experiences revealed how to create virtual environments that can contribute to program quality. Authors of this paper recommend virtual and face-to-face ECCE program administrators consider inclusion of the Awareness Integration Theory into their work with staff, children, and families. The following information is a discussion of the theory.

The Awareness Integration Theory originated, was developed, and researched by physiotherapist Dr. Foojan Zeine, by integrating elements from several phycological methods such as Cognitive Behavioral Therapy (CBT), Existential Therapy, Person-Centered Therapy, Emotion-Focused Therapy (EFT), Mind-Body Therapy (MBT), Transactional Analysis, Solution-Focused Therapy, Eye Movement Desensitization and Reprocessing (EMDR), Mindfulness, and Hypnosis, to create a cohesive framework that addresses the complexity of human experiences. The AIT leads individuals through six phases, each examining life domains such as career, relationships, family, early experiences, self-identity, and existential topics like mortality, spirituality, and perceptions of a higher power. Each phase utilizes focused questions and specific objectives to encourage personal growth and healing. Covering diverse life areas is essential, as they may influence each other directly or indirectly. Skills gained in one domain can aid development in others, while unresolved trauma or limiting beliefs in one area can obstruct overall progress and future goals. This thorough examination aligns with AIT's integrative approach (Zeine, 2017). Additionally, AIT promotes self-reflection, self-analysis, and self-help practices, enabling individuals to identify, address, and manage stress. It further supports emotional regulation and cognitive mindfulness, guiding intentional actions that yield fulfilling results. Five out of six phases of the AIT is used in a proactive manner when implemented for young children to help them regulate their emotions, build self-esteem, self-confidence, and self-efficacy. Phase 4 of the AIT is used in a modified manner with children.

The following are the six phases of AIT:

Phase 1: This initial phase seeks to heighten awareness of one's beliefs, emotions, and behaviors within the context of their environment, emphasizing how these factors impact their lives (parenting style, teaching style, behaving towards children). Assessing core beliefs related to areas of desired success is essential (Zeine, 2021). Conflicting intentions or hidden dualities can often hinder goal achievement. Recognizing positive beliefs that facilitate progress is just as important as identifying limiting beliefs that obstruct effective learning or success.

Phase 2: This phase has three primary goals: (1) Enhancing awareness of how individuals perceive others' opinions and feelings toward them, (2) Improving skills in observing and interpreting others' actions, and (3) Acknowledging how these perceptions affect one's life (Zeine, 2021). Assumptions about others can create fears and resistance to goal pursuit, with fear of judgment often being a significant obstacle. Distinguishing reality from assumptions and developing the ability to perform reality checks allows for a more focused approach to achieving one's goals.

Phase 3: This phase aims to raise awareness of one's beliefs, emotions, and self-concept as they operate across different life areas. By understanding how one's established sense of identity interacts with these domains, individuals can begin modifying core beliefs that cause stagnation (Zeine, 2021). This stage also reveals negative core beliefs formed from past trauma or adverse childhood experiences (parents, educators, staff members). Recognizing these beliefs provides a chance to reshape them constructively within one's psychological framework.

Phase 4: This phase centers on integrating past experiences with the present, exploring how emotional schemas are stored in the body as memories, often filled with intense emotions. It connects related memories, traumas, and beliefs, reframing negative beliefs through visualization to reflect strengths, resilience, and abilities (Zeine, 2021). By connecting current strengths to previously limiting beliefs, this integration supports coaching and mentoring by addressing subconscious barriers.

Phase 5: In this phase, individuals define core values to guide their lives, making conscious choices about beliefs and actions that align with these values. This includes recognizing existing strengths and identifying skill areas to reach goals, fostering a renewed mindset and self-image. Life goals are set with an action plan, and coaches assist clients in building self-awareness while implementing actions toward meaningful outcomes (Zeine, 2021).

Phase 6: The final phase focuses on establishing sustainable frameworks to maintain progress, creating a supportive network to help realize goals and choosing an accountability partner to ensure consistent follow-through (Zeine, 2021). This creates a lasting support system that continues beyond the mentoring phase.

Usage of AIT has helped parents and childcare staff recognize their beliefs and fears in parenting a child or caring for children, reviewing the effects of their beliefs, fears, and other emotions on themselves and on children, and them changing or modifying them to achieve their desired results. Usage of AIT with young children helps increase their emotional intelligence, self-esteem, self-efficacy, caring for others, understanding of others' emotions and feeling, behaving properly towards others, acting in a kind and inclusive way, and being responsible for their actions. Children have shown themselves to be more attentive to their peers needs, solution driven, deeper thinkers, more conditionate, have a higher level of love of learning, and more understanding of others' needs.

References

Akin, L., & Gözel, M.G. Understanding dynamics of pandemics. T*urkish Journal of Medical Sciences, 50*, 515-519. https://doi.org/10.3906/sag-2004-133

Annansingh, F. (2019). Mind the gap: Cognitive active learning in virtual learning environment perception of instructors and students. *Education and Information Technologies, 24*: 3669-3688. https://doi.org/10.1007/s10639-019-09949-5

Bagwell, J. (2020). Leading through a Pandemic: Adaptive leadership and purposeful action. *Journal of School Administration Research and Development, S1*(5), 30-34. https://doi.org/10.32674/jsard.v5iS1.2781

Bilal, H. E., Akbar, A., Yasmin, F., Rahman, A.U., & Li, S. (2022). Virtual learning during the COVID-19 pandemic: A bibliometric review and future research agenda. *Risk Management and Healthcare Policy, 15*: 1353-1368. https://doi.org/10.2147/RMHP.S355895

Braun, V., & Clark, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3(*2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Cadima, J., Doumen, S., Verschueren, K., & Buyse, E. (2015). Child engagement in the transition to school: Contributions of self-regulation, teacher–child relationships and classroom climate. *Early Childhood Research Quarterly, 32*, 1-12.

Cantor, P., Learner, R. M., Pittman, K. J., Chase, P. A., & Gamperts, N. (2021). *Whole- child development, learning, and thriving: A dynamic systems approach*.

CASEL. (2013). Effective social and emotional learning programs: Preschool and elementary school edition. https://files.eric.ed.gov/fulltext/ED581699.pdf

Champeaux, H., Mangiavacchi, L., Marchetta, F., & Piccoli, L. (2022). Child development and distance learning in the age of COVID-19. *Review of Economics of the Household, 20*: 659-685. https://doi.org/10.1007/s11150-022-09606-w

Chang, Y. (2022). Using the ISTE standards to examine the roles of teacher and students in technology-enhances learning environments. *Center for Teacher Education*.

Chen, C.C. & Huang, P.H. (2023). The effects of STEAM-based mobile learning on learning achievement and cognitive load. *Interactive Learning Environments, 31*(1): 100-116. https://doi.org/10.1080/10494820.2020.1761838

Chen, J. J., & Brotherson Adams, C. (2022). Drawing from and expanding their toolboxes: Preschool teachers' traditional strategies, unconventional opportunities, and novel challenges in scaffolding young children's social and emotional learning during remote instruction amidst COVID-19. *Early Childhood Education Journal*. https://doi.org/10.1007/s10643-022-01359-6

Chiu, T. K. F., Lin, T. J., & Lonka, K. (2021). Motivating online learning: The challenges of COVID-19 and beyond. *Asia-Pacific Education Researcher, 30*(3); 187-190. https://doi.org/10.1007/s40299-021-00566-w

Daum, D., Goad, T., Killian, C.M., & Schoenfeld, A. (2021). How do we do this? Distance learning in physical education-Part 1. *Journal of Physical education, recreation & Dance, 92*(4). https://doi.org/10.1080/07303084.2021.1886836

Davies, C., Kong, S. P., …& Gonzalez-Gomez, N. (2023). Sustained benefits of early childhood education and care (ECEC) for young children's development during COVID-19. Journal of Early Childhood Research, 22(2). https://doi.org/10.1177/1476718X231213488

Di Malta, G., Bond, J., Conroy, D., Smith, K., & Moller, N. (2022). Distance education students' mental health, connectedness, and academic performance during COVID-19: A mixed-methods study. *Distance Education, 43*(1), 97-118. https://doi.org/10.1080/01587919.2022.2029352

Downer, J. T., Goble, P., Myers, S. S., & Pianta, R. C. (2016). Teacher-child racial/ethnic match within pre-kindergarten classrooms and children's early school adjustment. *Early Childhood Research Quarterly*, *37*, 26-38.

Jalongo, M. R. (2022). Introduction to the volume. In J. Pattnaik, & M. K. Jalongo (Eds.), *The impact of COVID-19 on early childhood education and care: International perspectives, challenges, and responses* (pp. 3-13). Springer.

Johnson, C.C., Walton, J.B., & Brammer Elliott, J. (2022). Online teaching in K-12 education in the United States: A systematic review. *Review of Educational Research, 93*(3). https://doi.org/10.3102/00346543221105550

Jung, K., & Barnett, W.S. (2021) Impacts of the pandemic on young children and their parents: Initial findings from NIEER's May-June 2021 preschool learning activities survey [Research report]. National Institute for Early Education Research. https://nieer.org/research-report/impacts-of-the-pandemic-on-young-children-and-their-parents-initial-findings-from-nieers-may-june-2021-preschool-learning-activities-survey

Hamutoglu, N.B., Gemikonakli, O., Duman, I., Kirksekiz, A., & Kiyici, M. (2020). Evaluating students experiences using a virtual learning environment: Satisfaction and preferences. *Education Technology Research and Development, 68*, 437-462. https://doi.org/10.1007/s11423-019-09705-z

Hansen, J.E., & Broekhuizen, M.L. (2021). Quality of the language-learning environment and vocabulary development in early childhood. *Scandinavian Journal of Educational Research, 65*(2): 302–317. https://doi.org/10.1080/00313831.2019.1705894

Hazaymeh, W.A. (2021). EFL students' perceptions of online distance learning for enhancing English language learning during COVID-19 pandemic. *International Journal of Instruction, 14*(3): 501–518. https://doi.org/10.29333/iji.2021.14329a

Kaimara, P., Oikonomou, A., & Deliyannis, L. (2022). Could virtual reality applications pose real risks to children and adolescents? A systematic review of ethical issues and concerns. *Virtual reality, 26*: 697-735. https://doi.org/10.1007/s10055-021-00563-w

Kamei, A., & Harriott, W. (2021). SEL in virtual settings: Intervention strategies. *International Electronic Journal of Elementary Education, 13*(3). 365-371. https://doi.org/10.26822/iejee.2021.196

Karatas T. O., & Tuncer, H. (2020). Sustaining language skills development of pre-service EFL teachers despite the COVID-19 interruption: A case of emergency distance education. *Sustainability, 12*. https://doi.org/10.3390/su12198188

Kassymova, G.K., Vafazov, F.R., Pertiwi, F.D., Akhmetova, A.I. & Begimbetova, G.A. (2021). Upgrading quality of learning with e-learning system. *Challenges of Science, IV*: 26-34. https://doi.org/10.31643/2021.04

Kirby, G., Douglass, A., Lyskawa, J., Jones, C., & Malone, L. (2021). Understanding leadership in early care and education: A literature review. OPRE Report 2021-02. Washington, D.C.: Office of Planning, Research and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services. https://www.acf.hhs.gov/sites/default/files/documents/opre/understanding-leadership-ECE-march-2021.pdf

Kriener-Althen, K., Newton, E.K., Draney, K., & Mangione, P.L. (2020). Measuring readiness for kindergarten using the desired results developmental profile. *Early Education and Development, 31*(5). https://doi.org/10.1080/10409289.2020.1743160

Kummanee, J., Nilsook, P., & Wannapiroon, P. (2020). Digital learning ecosystem involving STEAM gamification for a vocational innovator. *International Journal of Information and Education Technology, 10*(7). https://doi.org/10.18178/ijiet.2020.10.7.1420

Lister, K., Seale, J., & Douce, C. (2021). Mental health in distance learning: A taxonomy of barriers and enablers to student mental wellbeing. The Journal of Open, Distance and e-Learning, 38(2). https://doi.org/10.1080/02680513.2021.1899907

Logan, H., McFarland, L., & Cuming, T. (2021). Supporting educator well-being during the COVID-19 pandemic: A case study of leadership in early childhood education and care organisations. *Australasian Journal of Early Childhood, 46*(4), 309-321.

Majadly, H., Awad, N., & Amasha, M. (2024). Online learning in higher education- Learners' perceptions, interaction, flexibility and challenges. International Journal of Instruction, 17(3). https://doi.org/10.29333/iji.2024.17330a

Manoukian, E. (2022). Beware the ides of March: How the pandemic changed the way home-based child care providers do business. *Zero to Three Journal.*

Marcum, J., & Kim, Y. (2020). Oral language proficiency in distance English-language learning. *Calico Journal, 37*(2): 148-168. https://doi.org/10.1558/cj.37788

Movahedazarhouligh, S., & Jones, M. (2024). Leading in times of uncertainty: Early childhood directors navigating the COVID-19 pandemic. *Journal of Childhood, Education & Society, 5*(1), 89-103. https://doi.org:10.37291/2717638X.202451296

Panayiotou, M., Humphrey, N., & Wigelsworth, M. (2019). An empirical basis for linking social and emotional learning to academic performance. *Contemporary Educational Psychology, 56*, 193-204. https://www.sciencedirect.com/science/article/pii/S0361476X18303382

Peras, A. J. F., & Prudente, M. S. (2021). Student's perception to online distance learning (ODL) and socio-emotional skills during Covid-19 pandemic. *Journal of Higher Education Theory and Practice, 21*(15).

Pianta, R., Hamre, B., Downer, J., Burchinal, M., Williford, A., Locasale-Crouch, J., Scott-Little, C. (2017). Early childhood professional development: Coaching and coursework effects on indicators of children's school readiness. *Early Education and Development*, *28*(8), 956-975.

Rakow, K.E., Upsher, R.J., Foster, J.L.H., Byrom, N.C. & Dommett, E.J. (2023). "It ain't what you use. It's the way that you use it": How virtual learning environments may impact student mental wellbeing. *Education Science, 13*(7), 749. https://doi.org/10.3390/educsci13070749

Rayuwati, R. (2020). How educational technology innovates distance learning during pandemic crisis in remote areas in Indonesia? *International research Journal of Management, IT & Social Sciences, 7*(6), 161-166. https://doi.org/10.21744/irjmis.v7n6.1032

Reid, D. B. (2021). US principals' sensemaking on the future roles and responsibilities of school principals. *Educational Management Administration & Leadership, 49*(2), 251-267. http://dx.doi.org/10.1177/1741143219896072

Saldaña, J. (2016). *The coding manual for qualitative researchers, 3rd edition*. Sage Publishing.

Samuel, R., Ismail, I., & Mahmud, N. (2022). Mental wellness of students affected by online learning. *International Journal of Academic Research in Business and Social Sciences, 12*(6), 1203-1211. https://dx/.doi.org/10.6007/IJARBSS/v12-i6/13932

Septian, R., & Sukarmin, Y. (2020). The influence of physical education in virtual environment towards students activity in the New Normal Era: Student and teacher perceptions. *Proceedings of the 4th International Conference on Sports Sciences and Health.* https://doi.org/10.2991/ahsr.k.210707.010

Sodhar, I.N., Jalbani, A.H., Buller, A.H., & Sodhar, A.N. (2020). Tools used in online teaching and learning through lock-down. *International Journal of Computer Engineering in Research Trends, 7*(8). https://doi.org/10.22362/ijcert/2020/v7/i08/v7i0806

Stone-Johnson, C., & Miles Weiner, J. (2020), Principal professionalism in the time of COVID-19. *Journal of Professional Capital and Community, 5*(3/4), 367-374. https://doi.org/10.1108/JPCC-05-2020-0020

Suryatini, L. (2022). Increasing literature capabilities in early childhood with learning through YouTube social media and Whats'App groups. *Culture in the Frame of Multicultural Religiosity, 1*. https://doi.org/10.24090/nuraicon.v1i1.110

Tollman, P., Keenan, P., Mingardon, S., Dosik, D., Rizvi, S., & Hurder, S. (2021). *Getting smart about change management. In Mastering the science of organizational change* (pp. 79-100). DeGruyter.

Veraksa, A., Chursina, A., & Gavrilova, M. (2021). The effect of distance teaching experiences on educators' attitudes toward distance education for preschoolers. *Education Sciences, 11*(650). https://doi.org/10.3390/educsci11100650

Wang, Y., Xia, M., Guo, W., Xu, F., & Zhao, Y. (2022). Academic performance under COVID-19: The role of online learning readiness and emotional competence. *Current Psychology, 42*, 30562-30575. https://doi.org/10.1007/s12144-022-02699-7

Yildiz, S., Kilic, G. N., & Acar, I. H. (2022). Early childhood education during the COVID-19 outbreak: The perceived changing roles of preschool administrators, teachers, and parents. *Early Child Education Journal, 5*(51), 743-753. https://doi.org/10.1007/s10643-022-01339-w

Zeine, F. (2021). *Awareness integration therapy: Clear the past, create a new future, and live a fulfilled life now*. Cambridge Scholars.

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An Investigation of Science Teachers' Self-Efficacy of Inquiry-Based Teaching Method

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Abstract

With the impact of developing and changing science and technology, it is important to raise science literate individuals. It is important for teachers who employ inquiry-based learning to feel sufficiently competent to cultivate individuals who investigate, question, and reach knowledge on their own. The aim of this study is to investigate science teachers' inquiry-based teaching self-efficacy in terms of gender variable. The study also examined the level of inquiry-based science teaching self-efficacy of science teachers and the relationship between inquiry-based science teaching self-efficacy and age variable. The sample of the study consisted of a total of 105 science teachers (79 female and 26 male). "Research-Based Science Teaching Scale" was used as a data collection tool. The data were analyzed using SPSS-22 program. As a result of the analysis, there was no significant difference between the gender variable and inquiry-based self-efficacy. No significant relationship was found between the age factor and the scale. When the distributions of each statement were analyzed, it was seen that disagreement or indecision was mostly in the statements of 'asking questions and making explanations'.

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Introduction

Education is a journey that involves many factors and the main character of this journey is the teacher. The teacher does not manage this journey, guides it. The teacher looks at children not as memorization machines but as participants on this journey. Knowledge is not a ready-made product, it is "alive". Thus, the era of transferring memorization is over (MEB, 2019). Accurate and complete learning of basic knowledge and concepts is essential for science education in order to learn the knowledge and concepts they will encounter in the future. Inaccuracies and deficiencies in comprehension lead to errors in learning advanced knowledge. For this reason, science teaching at the primary education level is very important (Ebren Ozan & Karamustafaoğlu, 2020).

As a world, we need young people who can adapt to scientific and technological developments, research, observe, solve problems and questions. Therefore, in order to raise individuals with these skills, developed countries work more sensitively on their education systems and create appropriate programs that contain the desired goals (Tatar & Kuru, 2006). Constructivism initially emerged as a theory concerning individuals' way of learning knowledge. Over time, this process evolved into an approach focusing on how individuals construct knowledge (Erdem & Demirel, 2002). In the constructivist approach, individuals find and process information themselves and the teacher acts as a guide. The teacher creates an environment of questioning and discussion with students. Thus, more meaningful, effective and permanent learning is realized through such activities (Yaşar & Duban, 2009).

The inquiry-based approach is based on constructivism. The most important thing is to learn how to learn (Tatar & Kuru, 2006). Inquiry-based activities provide students with the skills of questioning, criticizing, understanding and making sense of life and help them develop scientific process skills. Inquiry-based learning approach is based on John Dewey's ideology that "Education begins with the learner's sense of curiosity" (Boğar, 2019).

Inquiry is the act of asking questions while learning new information, utilizing your attitudes and skills. Inquiry-based learning approach provides students with the skills of problem solving, discovery, questioning, research, curiosity, critical and creative thinking, comprehending and making sense of their experiences (Avcı & Kırbaşlar, 2023). The basis of inquiry-based learning is to teach students to produce solutions to problems by adopting the methods and ways that scientists use in their research. In this way, students use observation, research and inquiry methods like scientists to understand and make sense of nature and what happens in their lives and to reach conclusions. The teacher's task here is to design and create the learning environment according to the inquiry-based learning approach. If the teacher prepares this process and environment well, students can recognize problems, ask questions, make predictions, formulate definitions, form hypotheses and test them, use different research methods, and establish a relationship between their experiences and scientific knowledge (Ünal, 2018).

In inquiry-based learning, it is not the teacher's task to teach concepts, facts and information as in the traditional method. The main task of the teacher is to help and guide the students. The teacher has the role of facilitating and guiding students in the inquiry process. The teacher uses different techniques and methods in the inquiry process, serves as a model for the students, has a good command of body language (Çavuşlu, 2014). In inquiry-based learning method, students ask questions, form hypotheses to solve questions and test them, collect data, record and analyze the data they collect, and construct the results. However, studies also reveal that inquiry-based teaching method can only be implemented by teachers with high self-efficacy (Dawson et al., 2006). Self-efficacy first appeared in Bandura's Social Learning Theory. Self-efficacy is the belief in one's capacity and ability to succeed in the activity required to perform a certain performance (Bandura, 1994; as cited in Yılmaz & Gürçay, 2011).

It is thought that self-efficacy was effective in improving teachers' teaching behaviors. The training of teachers who are selfless, capable of coping with challenges, eager, and able to fulfill the competencies of the teaching profession is achievable through enhancing teachers' self-efficacy (Yılmaz & Gürçay, 2011). Inquiry-based learning approach has been the subject of many studies in the field of education until today. It has been encountered that teachers are undecided about the inquiry-based teaching method that they will integrate into the lessons, and some teachers think that it is easy and some teachers think that it is difficult in practice. In dedication to this, the research question was found through this problem in the study and the research was conducted based on the literature review. In this context, the research question of the study was determined as follows.

“What is the level of inquiry-based teaching self-efficacy of science teachers and is there a difference according to gender?" The following sub-problems were identified for this problem situation.

1. What is the level of science teachers' inquiry-based science teaching self-efficacy?
2. Is there a significant difference between science teachers' inquiry-based science teaching self-efficacy and gender?
    a) Is there a significant difference between the sub-dimension of opportunity and gender?
    b) Is there a significant difference between the sub-dimension of guidance and gender?
    c) Is there a significant difference between the sub-dimension of evidence and gender?
    d) Is there a significant difference between the sub-dimension of explanation and gender?
3. Is there a significant relationship between inquiry-based science teaching self-efficacy and age?

Method

Research Model

In this study, the survey model, one of the descriptive research methods, was used as the research model. According to Karasar (2012), survey models are research approaches that aim to describe a past or current situation as it exists. In this model, the event, individual or object that is the subject of the research is tried to be handled within its own conditions, and we can observe the thoughts without changing them.

Working Group

The sample of the study consisted of a total of 105 science teachers (79 female and 26 male). Easily accessible case sampling, one of the purposive sampling methods, was used in the study. In this method, the closest or easily accessible individuals are selected until the required sample size is reached (Cohen et al., 2007).

Data Collection Tool

Scales are measurement tools developed to reveal a certain psychological structure (Ekiz, 2013). For this reason, in this study, the Likert-type "Research-Based Science Teaching Self-Efficacy Scale" consisting of 69 items and 4 sub-dimensions developed by Smolleck (2006) and adapted by Akçay and İnaltekin in 2011 was used as a data collection tool after obtaining permission to use it. The scale is a 5-point Likert type, with response options including "Strongly Agree," "Agree," "Undecided" "Disagree," and "Strongly Disagree." The original version of the scale, developed by Smolleck (2006), comprised 69 items across 4 subdimensions and was tested with 190 teacher candidates, resulting in a Cronbach's Alpha coefficient of .68. The Turkish adaptation of the scale by Inaltekin and Akçay (2011) involved 281 teacher candidates and yielded a Cronbach's Alpha coefficient of .83. The subdimensions include Opportunity (18 items), Guidance (19 items), Evidence (17 items), and Explanation (15 items).

Data Analysis

The statistical analysis of the data collected through the Google Form address was analyzed using SPSS (Statistical Package for Social Sciences) 22.0 program. One Sample Kolmogorov-Smirnov test was applied to find out whether the teachers' responses to the scale were normally distributed, and skewness and kurtosis values were examined. The dimensions were normally distributed. Since the scale and sub-dimensions were normally distributed, parametric tests were used. However, since the number of male teachers in the gender variable was less than 30, Mann Whitney-U Analysis was used. In normally distributed data, parametric tests can be used if the number of samples is less than 30 (Kul, 2014; Sümbüloğlu & Sümbüloğlu, 2007). Since the age variable did not show a normal distribution, non-parametric test was used. A frequency table was created for sociodemographic questions. In order to see the differences in the group averages of the gender variable, Mann Whitney-U Analysis was applied for variables with 2 groups. Pearson correlation analysis was applied to determine the direction and strength of the relationship between the research-based science teaching self-efficacy scale and the sub-dimensions of opportunity, guidance, evidence, explanation, and Spearman correlation analysis was applied to determine the direction and strength of the relationship between the scale, sub-dimensions and age variable.

Results

Normality Assumption Analysis and Reliability Analysis

One Sample Kolmogorov-Smirnov test was applied to find out whether the teachers' responses to the scale were normally distributed, and skewness and kurtosis values were examined.

Table 1. Normality Assumption Analysis and Reliability Analysis

Scale	N	M	Sd	Kolmogorov Smirnov	Skewness	Kurtosis	Cronbach Alpha
Opportunity	105	74,60	7,92	,045	-,629	,131	,899
Guidance	105	74,98	7,59	,000	-,712	-,249	,895
Evidence	105	66,34	6,87	,000	-,727	-,425	,893
Explanation	105	83,39	10,12	,004	-,864	,420	,867
Total	105	299,31	30,23	,036	-,763	,008	,966
Age	105	26,49	3,94	,000	2,579	11,394	-

Since the kurtosis and skewness values of the scales did not exceed the -2; +2 limit, it was assumed that they showed normal distribution and parametric tests were used in the analyzes. Since the kurtosis and skewness values for the age variable exceeded the -2; +2 limit, non-parametric tests were used in the analyzes (George & Mallery, 2010).

A Cronbach Alpha coefficient between 0.60 and 0.80 indicates that the scale is reliable, and a coefficient between 0.80 and 1.00 indicates that the scale is highly reliable. Within the framework of this information, as seen in Table 1, the Cronbach Alpha values of the scale and its sub-dimensions were between 0.80 and 1.00 and their reliability was at a high level (Kayış, 2009; Kılıç, 2016).

As seen in Table 1, the Cronbach Alpha internal consistency coefficient for the whole scale was found .966. When we examined the Cronbach Alpha values of the sub-dimensions, we found .899 for the "opportunity" dimension, .895 for the "guidance" dimension, .894 for the "evidence" dimension and .867 for the "explanation" dimension. Based on these data, it was observed that the scale we used was sufficiently reliable.

Correlation Analysis between Sub-Dimensions

Research-Based Science Teaching Scale is consisting of 4 sub-dimensions. Pearson correlation analysis was applied to determine the direction and strength of the relationship between the research-based science teaching self-efficacy scale and the sub-dimensions of opportunity, guidance, evidence and explanation. The correlation between these sub-dimensions was analyzed in Table 2.

Table 2. Correlation Analysis between Opportunity, Guidance, Evidence, Explanation Sub-dimensions

	1	**2**	**3**	**4**	**5**
Opportunity (1)	1				
Guidance (2)	,934** ,000	1			
Evidence (3)	,877** ,000	,902** ,000	1		
Explanation (4)	,699** ,000	,739** ,000	,836** ,000	1	
Total (5)	,930** ,000	,948** ,000	,963** ,000	,893** ,000	1

*Correlation is significant at 0.05 level. ** Correlation is significant at 0.01 level.

If the Pearson product-moment correlation coefficient is between 0.30 and 0.70, there is a medium level relationship, and if it is between 0.71 and 0.99, there is a high-level relationship (Köklü et al., 2006). There was a positive and highly significant relationship between Opportunity Subdimension and Guidance Subdimension with 99% confidence (r=.934; p=.000), between Opportunity Subdimension and Evidence Subdimension with 99% confidence (r=,877; p=,000), between Opportunity Subdimension and Total Scale with 99% confidence (r=,930; p=,000), between Guidance Subscale and Evidence Subscale with 99% confidence (r=,902; p=,000), between Guidance Subdimension and Explanation Subdimension with 99% confidence (r=,739; p=,000), between the Guidance Subscale and the Total Scale with 99% confidence (r=,948; p=,000), between the Evidence Subscale and the Explanation Subscale with 99% confidence (r=,836; p=,000), between the Evidence Subscale and the Total Scale with 99% confidence (r=,963; p=,000), between the Explanation Subscale and the Total Scale with 99% confidence (r=,893; p=,000) and there was a positive and moderately significant relationship between the Opportunity Subdimension and the Explanation Subdimension with 99% confidence (r=,699; p=,000).

When the relationship between Opportunity, Guidance, Evidence, and Explanation sub-dimensions is analyzed, it is seen that the highest correlation is between Opportunity sub-dimension and Guidance sub-dimension with a value of .934, and the lowest correlation is between Opportunity sub-dimension and Explanation sub-dimension with a value of .699.

Frequency Analysis of Sub-Dimensions

As a result of the analysis, a frequency table was created for each sub-dimension. Teachers' responses were analyzed separately for each sub-dimension, and as a result of the analysis, it was noticed that there were more different opinions in the distribution of some items and these items were analyzed.

Examination of the Opportunity sub-dimension

Opportunity sub-dimension consists of 18 items. The frequency table of the Opportunity sub-dimension was examined, and the answers given to 3 items attracted attention and the answers given were shown in Table 3.

Table 3. Frequency Table of Opportunity Subdimension Statements

	Strongly Disagree		**Disagree**		**Undecided**		**Agree**		**Strongly Agree**	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
I give students the chance to formulate their own research questions.	2	%1,9	15	%14,3	17	%16,2	32	%30,5	39	%37,1
I expect my students to ask scientific questions.	2	%1,9	9	%8,6	16	%15,2	36	%34,3	42	%40,0
My students decide which evidence would be most useful in answering a scientific question or questions.	3	%2,9	10	%9,5	15	%14,3	33	%31,4	44	%41,9

When the statements in the Opportunity sub-dimension were analyzed, it was seen that teachers frequently gave opportunities to their students in different fields. However, the frequencies of the statements given in Table 3 in this sub-dimension draw attention.

Examination of the Guidance sub-dimension

Guidance sub-dimension consists of 19 items. The frequency table of the guidance sub-dimension was examined, and the answers given to 4 items attracted attention and the answers given were shown in Table 4.

Table 4. Frequency Table of Guidance Subdimension Statements

	Strongly Disagree		**Disagree**		**Undecided**		**Agree**		**Strongly Agree**	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
When investigating scientific phenomena, my students have a choice of questions I give them.	3	%2,9	6	%5,7	15	%14,3	34	%32,3	47	%44,8
I play a decisive role in defining scientific questions.	0	%0,0	4	%3,8	19	%18,1	48	%45,7	34	%32,4
I guide students to scientifically accepted ideas for better understanding of science subjects.	0	%0,0	4	%3,8	17	%16,2	38	%36,2	46	%43,8
Students construct scientific explanations using evidence with my help.	2	%1,9	3	%2,9	16	%15,2	43	%41,0	41	%39,0

When the statements in the guidance sub-dimension were analyzed, it was seen that teachers mostly guide their students in many areas. However, the answers given to 4 statements in Table 4 in this sub-dimension draw attention.

Examination of the Evidence sub-dimension

The evidence sub-dimension consists of 17 items. The frequency table of the evidence sub-dimension was examined, and the answers given to 2 items attracted attention and the answers given were shown in Table 5.

Table 5. Frequency Table of Evidence Subdimension Statements

	Strongly Disagree		Disagree		Undecided		Agree		Strongly Agree	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
My students construct their explanations using the evidence given to them.	2	%1,9	6	%5,7	14	%13,3	35	%33,4	48	%45,7
My students construct their explanations based on evidence according to the method I present to them.	1	%1,0	14	%13,3	15	%14,3	40	%38,1	35	%33,3

When the statements in the evidence sub-dimension were analyzed, it was observed that students generally used and presented evidence, while teachers provided supportive ideas and evidence to students in this process.

Examination of the Explanation sub-dimension

The explanation sub-dimension consists of 15 items. The frequency table of the explanation sub-dimension was examined, and the answers given to 5 items attracted attention and the answers given were shown in Table 6.

Table 6. Frequency Table of Explanation Subdimension Statements

	Strongly Disagree		Disagree		Undecided		Agree		Strongly Agree	
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**
I ask most of the scientific questions that students need to do research.	8	%7,6	27	%25,7	28	%26,7	26	%24,8	16	%15,2
Students choose the questions they want to investigate from a list of questions given to them.	2	%1,9	15	%14,3	12	%11,4	37	%35,2	39	%37,1

My students analyze the data presented to them according to the teacher's narration.	3	%2,9	14	%13,3	20	%19,0	43	%41,0	25	%23,8
I provide students with all the evidence they need to construct explanations through the lectures and the textbook.	8	%7,6	26	%24,8	18	%17,1	25	%23,8	28	%26,7
I expect my students to follow predetermined methods when defending their explanations.	0	%0,0	6	%5,7	25	%23,8	35	%33,4	39	%37,1

When the statements in the Explanation sub-dimension were analyzed, it was seen that teachers mostly guide their students in many areas. However, the answers given to 5 statements in Table 6 in this sub-dimension draw attention.

Is There a Significant Difference between Science Teachers' Self-Efficacy in Inquiry-Based Science Teaching and Gender?

Table 7 shows the sociodemographic information of the teachers who participated in this study. This study included 79 female (75.2%) and 26 male (24.8%) participants.

Table 7. Socio-Demographic Information

Variable	**Group**	**N**	**Percentage (%)**
Gender	Female	79	75,2
	Male	26	24,8

In order to see the differences in the group averages of the gender variable, Mann Whitney-U Analysis was applied for variables with 2 groups. Mann Whitney-U Analysis was given in Table 8.

Table 8. Mann Whitney-U Analysis for Gender Variable

Scale	Group	N	M	Sd	Z	df	p*
Opportunity	Female	79	75,17	7,12	-,869	88	,385
	Male	26	72,71	10,11			
Guidance	Female	79	75,36	6,85	-,244	88	,807
	Male	26	73,71	9,71			
Evidence	Female	79	66,46	7,05	-,487	88	,626
	Male	26	65,95	6,41			
Explanation	Female	79	83,00	10,70	-,463	88	,643
	Male	26	84,67	7,98			
Total	Female	79	300,00	29,77	-,329	88	,742
	Male	26	297,05	32,34			

*p<0,05

According to the gender variable groups, the opportunity subdimension score of female teachers was 2.46 points higher than male teachers. However, there was no statistically significant difference (p=,385>0.05). The guidance subdimension score of female teachers was 1,65 points higher than male teachers. However, there was no statistically significant difference (p=,807>0,05). The evidence subdimension score of female teachers was 0,51 points higher than male teachers. However, there was no statistically significant difference (p=,626>0,05). The explanation subdimension score of male teachers was 1,67 points higher than female teachers. However, there was no statistically significant difference (p=,643>0,05). The Total Scale Score was found to be approximately 3 points higher for female teachers, but there was no statistically significant difference (p=,742>0.05).

Is There a Significant Relationship Between Inquiry-Based Science Teaching Self-Efficacy and Age?

Spearman's correlation analysis was applied to determine the direction and strength of the relationship between inquiry-based science teaching self-efficacy scale, opportunity, guidance, evidence, explanation sub-dimensions and age variable. Table 9 shows the correlation between these sub-dimensions.

Table 9. Correlation Analysis between Inquiry-Based Science Teaching Self-Efficacy and Age Variables

	Opportunity	Guidance	Evidence	Explanation	Total
Age	-,195 ,065	-,071 ,507	-,114 ,285	,202 ,056	-,051 ,633

*Correlation is significant at 0.05 level.

There was no significant relationship between the Opportunity Subdimension and the age variable (r=-.195; p=.065), between the Guidance Subdimension and the age variable (r=-.071; p=.507), between the Evidence Subscale and the age variable (r=-.114; p=.285), between the Explanation Subscale and the age variable (r=-.202; p=.056), between inquiry-based science teaching self-efficacy and age variable (r=-,051; p=,0633).

Discussion and Conclusion

Rather than raising individuals who memorize existing scientific knowledge, the main purpose of science education is to raise individuals who understand the concepts of science, can find relevance between concepts, have scientific process skills, and can access information on their own (Atasoy et al., 2007; Şahin, 2023). In order to raise science literate individuals, it is important to provide students with accurate and complete basic knowledge and concepts, to enable students to adapt what they learn to their daily lives and to gain scientific process skills (Kayacan & Selvi, 2017).

In the Opportunity sub-dimension, more disagreement and indecision were observed in 3 statements compared to the other statements. It was seen that these 3 items were related to students' asking and answering questions. Since the 2013 science curriculum, it has been emphasized to use the inquiry method in which students are active in learning and responsible for their own learning. It has been emphasized that students should be individuals who question, research and think critically (MEB, 2013; MEB, 2018). For this, students need to think, generate questions and ask questions to reach the right information.

Questions have a very important place in inquiry-based teaching. The teacher is only in the role of a guide and the student is expected to manage the process. When we look at the beginning of the process, there should be a problem and the student should form questions about this problem, this method is called open inquiry-based method. In the open inquiry process, students investigate questions with the methods they design and choose. Students make their own decisions at each step of open inquiry. In this type of inquiry, which requires high-level thinking skills, one of the most important tasks of teachers is to motivate students to ask their questions (Cin & Türkoğuz, 2017). As a result of an extensive search of a range of literature, it has been observed that open inquiry-based instruction has a positive effect on students' academic achievement, self-confidence, and taking responsibility. However, even if all the responsibility of open-ended inquiry-based teaching is seen on the student, the teacher's obligation is very high. When the literature is examined, it is seen that teachers are indecisive and face obstacles for this teaching. Kaya and Yılmaz (2016) found in their study that the effect of open inquiry-based teaching on students' academic achievement is undeniable and that teachers are uncertain about how to provide support and guidance in this process. A similarity was observed with the study.

In the guidance sub-dimension, more disagreement and indecision were observed in 4 statements compared to the other statements. These statements were related to the teacher's help and guidance of the student. In guided inquiry, the problem to be investigated is given by the teacher. Students plan the process and obtain the result. Keçeci (2014) stated in his research that students preferred the guided inquiry method the most in the applications carried out with the inquiry method. He explained this situation as 5th and 6th grade students' need for teacher guidance. For this, it is thought that teachers should be competent in this process. Bayram (2015) examined the difficulties encountered by pre-service teachers while preparing activities with guided inquiry method. As a result of the research, he encountered 6 difficulties. One of them is the guidance dimension of internal difficulties. It was observed that pre-service teachers had concerns about guiding the inquiry process and the ideology of the process. There was a similarity with this study. When we look at the process, inquiry-based learning method is a method that can be used not only to teach subject matter to students but also to raise individuals who have adopted skills such as research, problem solving and questioning.

In the evidence sub-dimension, more disagreement and indecision were observed in 2 statements compared to the other statements. These statements are about students presenting their explanations according to the evidence and methods given by the teachers. In the study conducted by Bayram (2015), it was seen that pre-service teachers faced difficulties in this regard. It was found that the prospective teachers were concerned about whether the students would follow a new process and method based on the process they designed or their own thoughts, whether they would explain from the information they provided or with their own thoughts. In such problems, it is very important which type of inquiry we choose. If we choose the structured inquiry method, we need to apply the process and method according to the steps given by the teacher. Based on the information and evidence provided by the teacher, students were expected to make explanations and draw conclusions.

In the explanation sub-dimension, more disagreement and indecision were observed in 5 statements compared to the other statements. These statements are related to the teacher asking the questions, students choosing the questions from the list, the teacher giving the evidence, the method they follow and analyzing the data according to the teacher's method. It was seen that these problems were equivalent to the problems seen in the opportunity, guidance and evidence sub-dimensions. According to Perry and Richardson, (2001), Wood, (2003), Branch and Solowan, (2003), Zacharia, (2003), Jorgenson, Cleveland and Vanosdall, (2004), inquiry-based learning is defined as the process of learning through asking questions, conducting research and analyzing the findings and transforming the acquired data into useful information. It is also a process in which problems are created and students try to solve these problems in the course. Inquiry-based learning is a student-centered approach that focuses on critical thinking, asking questions, problem solving and research. With inquiry-based learning, learning by using critical thinking and scientific process skills rather than memorizing concepts has come to the forefront. Inquiry-based science teaching has moved away from the teaching of memorizing the book, in which information is given directly, and has adopted a student-centered approach in which students are active, learn by doing and living (Yaşar & Duban, 2009).

According to Altunsoy (2008), the benefits of inquiry-based learning include increasing interest and curiosity in the subject, being motivating due to active learning, giving importance to variables and attracting attention, making sense of the answer rather than defining it, and providing faster and more frequent feedback. With these advantages of inquiry-based learning, it is possible to raise individuals who can compete with individuals in developed countries; individuals with high academic achievement, who have and adopt scientific process skills, who have a good level of cognitive development, etc.

No significant difference was found between science teachers' inquiry-based teaching self-efficacy and gender variable. From the total scale scores, it was concluded that female teachers scored slightly higher than male teachers and had more positive self-efficacy. In a study conducted on physics and chemistry teachers, it was mentioned that female teachers exhibited more positive self-efficacy in the classroom (Jones & Wheatley, 1990).

When studies in the literature were examined, there were studies that have similar findings and there was no significant difference between genders (Akbaş & Çelikkaleli, 2006; Gencer & Çakıroğlu, 2007; Gökdağ Baltaoğlu et al. 2015; Yaman et al., 2004). In addition, there were also studies that found significant differences between genders that contradicted the findings (Aktamış et al., 2016; Çavuşlu, 2014; Kocagül, 2013).

Akbaş and Çelikkaleli (2006) examined whether pre-service teachers' science teaching self-efficacy beliefs differed according to gender variable. As a result of the study, it was found that self-efficacy beliefs towards science teaching did not differ according to gender. Avcı (2019) studied many factors and relationships in his research with pre-service science teachers. While examining inquiry-based science teaching beliefs, he also investigated the gender variable. The result of the study is similar to this study. Avcı found that the gender variable did not cause a significant difference, but the averages of female pre-service teachers were slightly higher than male pre-service teachers. Çavuşlu (2014) examined inquiry-based views using the Inquiry-Based

Science Teaching Scale in a study conducted with pre-service science and technology teachers. He found that there was a significant difference between pre-service teachers' inquiry-based science teaching self-efficacy and gender variable. It was seen that the significant difference was positive in the direction of female pre-service teachers.

Kocagül (2013) conducted a one-group pre-test post-test study with science and technology teachers and examined the differences in beliefs, self-efficacy and skills towards inquiry-based teaching according to gender. It was found that there was a statistically significant difference in inquiry-based self-efficacy according to gender before and after the application. Male teachers increased more than female teachers before and after the implementation and a significant difference was found.

When the data on the Opportunity sub-dimension were analyzed, it was observed that female teachers were more understanding and gave opportunities to their students to improve themselves in every sense compared to male teachers. When the guidance sub-dimension data were analyzed, it was observed that female teachers were more understanding and guided their students than male teachers. When the evidence sub-dimension data were analyzed, it was observed that female teachers scored higher than male teachers in the cases of giving examples and evidence to students, creating and presenting students' associations and explanations of events using evidence. The data obtained in 3 sub-dimensions were similar to the study conducted by Çavuşlu (2014). When the explanation sub-dimension data were examined, it was observed that male teachers scored higher than female teachers and had positive thoughts in the cases where students analyzed the situation, made explanations and teachers made explanations where necessary. There was no similarity with the study conducted by Çavuşlu (2014) because it was observed that there was no significant relationship between the explanation sub-dimension and gender.

In the study, no relationship was found between the scale and sub-dimensions of science teachers and the age variable. When studies in the literature were examined, there are studies that are similar to the findings and there is no significant difference between age (Açıkgöz & Uluçınar Sağır, 2020; Kaçar & Beycioğlu, 2017; Silsüpür & Bilican, 2021). These researchers stated that there was no relationship between self-efficacy belief and age in their studies. Silsüpür and Bilican (2021) examined the opinions of classroom teachers about inquiry-based teaching and their self-efficacy according to the factors in his study; there was no significant difference in the self-efficacy levels of classroom teachers according to the age factor. There was a similarity with this study.

There is no single way of learning. Different methods may be needed for better learning on this path. The use of inquiry-based teaching method in lessons has many effects on students' academic, cognitive and skills. It was found that students' learning was positively affected especially when the science course, which has many abstract concepts and misconceptions, was taught with the inquiry-based method. In order to apply this method in lessons, teachers should have high self-efficacy and be competent in the method. It is possible that teachers with high self-efficacy in inquiry-based teaching method are more successful in terms of knowledge accumulation, process management, providing support, and that it is also effective in terms of students adapting to the process and being active in the process.

Recommendations

Based on the results of this study, suggestions for researchers are listed below:

- In order to cultivate students who possess the principles embraced by the curriculum and the skills it aims to develop, there is a need for competent teachers who possess those skills. For this purpose, inquiry-based education courses that will develop competencies and impart the desired skills are necessary.
- Concrete prefixes and activities can be included in the curriculum.
- In-service practice trainings that provide information about inquiry-based education method can be increased and teachers can participate in these trainings.
- The sample can be expanded in future studies.
- A study comparing science teachers and pre-service science teachers can be conducted.
- Teachers can be interviewed to identify problems in the results of the scale (it can be supported with qualitative research as well as quantitative research).
- Demographic questions can be diversified (age, university attended, year graduated from university, years in the profession, ...).

References

Açıkgöz, D., & Uluçınar Sağır, Ş. (2020). Investigation of science teachers' awareness towards inquiry based teaching, *Karaelmas Journal of Educational Sciences, 8(*1), 10-26.

Akbaş, A., & Çelikkaleli, Ö. (2006). The investigation of the preservice elementary teachers' science instruction self-efficacy beliefs according to their gender, type of education, and universities, *Mersin University Journal of the Faculty of Education, 2* (1), 98-110. https://doi.org/10.17860/efd.53326.

Akçay, H., & İnaltekin T. (2011). Adaptation of the research based science instruction scale to Turkish: The validity and reliability study, *Trakya University Journal of Education, 2*(1):157-185.

Aktamış, H., Özenoğlu Kiremit, H., & Kubilay, M. (2016). Investigation of students' self-efficacy beliefs according to science achievements and demographic characteristics, *Journal of Educational Sciences, 7*(2), 1-10.

Altunsoy, S. (2008). *Ortaöğretim biyoloji öğretiminde araştırmaya dayalı öğrenme yaklaşımının öğrencilerin bilimsel süreç becerilerine, akademik başarılarına ve tutumlarına etkisi [The effect of inquiry-based learning approach on students' science process skills, academic achievement and attitudes in secondary biology teaching].* [Masters dissertation, University of Selçuk].

Atasoy, B., Kadayıfçı, H., & Akkuş, H. (2007). Exıibition of students' creative thoughts from their drawings and explanations, *The Journal of Turkish Educational Sciences, 5*(4), 679-700.

Avcı, M. (2019). *Fen bilgisi öğretmen adaylarının epistemolojik inançlarıyla sorgulamaya dayalı fen öğretimi inançları, bilimsel tutumları ve akademik başarıları arasındaki ilişkinin incelenmesi [Investigating the relationship between pre-service science teachers' epistemological beliefs, inquiry-based science teaching beliefs, scientific attitudes and academic achievement].* [Masters dissertation, University of Sinop].

Avcı, F., & Kırbaşlar, F. G. (2023). The investigation of secondary school students' self-regulation strategies, motivational beliefs and science related inquiry learning skills perception, *International Journal of Academic Studies in Technology and Education, 1*(2), 136–155. https://doi.org/10.55549/ijaste.14.

Bayram, Z. (2015). Investigating difficulties that preservice science teachers encounter while designing guided inquiry activities, *Hacettepe University Journal of Education, 30*(2), 15-29.

Boğar, Y. (2019). Literature review on inquiry-based learning in science education, *International Journal of Science and Education, 1*(2), 91-118.

Branch, J. L., & Solowan, D. G. (2003). Inquiry-based learning: The key to student success. *Library Skills. School Libraries in Canada, 22* (4); 6-12.

Cin, M., & Türkoğuz, S. (2017). The effect of inquiry based learning with innovative science experiments on conceptual understanding, *Western Anatolia Journal of Educational Sciences, 8*(2), 85-111.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education*, Routledge: London.

Çavuşlu, Z. (2014). *Fen ve teknoloji öğretmen adaylarının araştırma sorgulamaya dayalı öğretim hakkındaki görüşleri [Pre-service science and technology teachers' views on inquiry-based teaching]*. [Masters dissertation, University of Çanakkale Onsekiz Mart].

Dawson, K., Cavanaugh, C., & Ritzhaupt, A. D. (2006). Florida's EETT leveraging laptops initiative and its impact on teaching practices, *Journal of Research on Technology in Education, 41*(2), 143-159. https://doi.org/10.1080/15391523.2008.10782526.

Ebren Ozan, C., & Karamustafaoğlu, S. (2020). The effect of inquıry-based approach in the teaching of unit "Change of matter, *Trakya Journal of Education, 10*(3), 599-613. https://doi.org/10.24315/tred.547570

Ekiz, D. (2013). *Bilimsel Araştırma Yöntemleri [Scientific Research Methods]*. Anı Yayıncılık.

Erdem, E., & Demirel, Ö. (2002). Constructivism in curriculum development, *Hacettepe University Journal of Education,* 23, 81-87.

George, D., & Mallery, M. (2010). *SPSS for windows step by step: A simple guide and reference,* 17.0 Uptade (10a ed.) Boston: Pearson.

Gencer, A. S., & Cakiroglu, J. (2007). Turkish pre-service science teachers' self-efficacy beliefs regarding science teaching and their beliefs about classroom management, *Teaching and Teacher Education, 23*(5); 664-675. https://doi.org/10.1016/j.tate.2005.09.013

Gökdağ Baltaoğlu, M., Sucuoğlu H., & Yurdabakan, İ. (2015). Self-efficacy perceptions and success/failure attributions of prospective teachers: A longitudinal study, *Elementary Education Online, 14*(3), 803-814. https://doi.org/10.17051/io.2015.66489.

Jones, M. G., & Wheatley, J. (1990). Gender differences in teacher-student interactions in science classrooms, *Journal of Research in Science Teach, 27*(9), 861-874. https://doi.org/10.1002/tea.3660270906.

Jorgenson, O., Cleveland, J., & Vanosdall, J. (2004). *Doing good science in middle school: A practical guide to inquiry-based instruction*. Virginia: NSTA Press.

Kaçar, T., & Beycioğlu, K. (2017). The investigation of elementary school teachers' self-efficacy beliefs in terms of various variables, *Elementary Education Online, 16*(4), 1753-1767. https://doi.org/10.17051/ilkonline.2017.342988.

Karasar, N. (2012). *Bilimsel Araştırma Yöntemi [Scientific Research Method]*. Nobel Yayın Dağıtım.

Kaya, G., & Yılmaz, S. (2016). The impact of open inquiry based learning on students' achievement and development of science process skills, *Hacettepe University Journal of Education, 31*(2), 300- 318. https://doi.org/10.16986/HUJE.2016016811.

Kayacan, K., & Selvi, M. (2017). The effect of inquiry based learning enriched with self regulated activities on conceptual understanding and academic self efficacy, *Kastamonu Education Journal,* 25, 1771-1786.

Kayış, A. (2009). *Güvenirlik Analizi*: *SPSS Uygulamalı Çok Değişkenli İstatistik Teknikleri [Reliability Analysis: SPSS Applied Multivariate Statistical Techniques].* Ş. Kalaycı (Ed), Asil Yayıncılık.

Keçeci, G. (2014). *Araştırma ve sorgulamaya dayalı fen öğretiminin öğrencilerin bilimsel süreç becerilerine ve tutumlarına etkisi [The effect of inquiry-based science teaching on students' science process skills and attitudes].* [Doctoral dissertation, University of Fırat].

Kılıç, S. (2016). Cronbach's alpha reliability coefficient, *Journal of Mood Disorders, 6* (1); 47-48. https://doi.org/10.5455/jmood.20160307122823.

Kocagül, M. (2013). *Sorgulamaya dayalı mesleki gelişim etkinliklerinin ilköğretim fen ve teknoloji öğretmenlerinin bilimsel süreç becerilerine, öz- yeterlilik ve sorgulamaya dayalı öğretime ilişkin inançlarına etkisi [The effect of inquiry-based professional development activities on elementary science and technology teachers' science process skills, self-efficacy and beliefs about inquiry-based teaching]*. [Masters dissertation, University of Dokuz Eylül].

Köklü, N., Büyüköztürk, Ş., & Çokluk Bökeoğlu, Ö. (2006). *Sosyal Bilimler için İstatistik [Statistics for Social Sciences].* Pegem A Yayıncılık.

Kul, S. (2014). *Uygun istatistiksel test seçim kılavuzu [Guidance on choosing the appropriate statistical test]*. Plevra Bülteni, 8:26-29.

MEB (2013). *İlköğretim kurumları (ilkokullar ve ortaokullar) fen bilimleri dersi (3, 4, 5, 6, 7 ve 8. sınıflar) öğretim program [Primary schools (primary and secondary schools) science curriculum (grades 3, 4, 5, 6, 7 and 8)].* Talim ve Terbiye Kurulu Başkanlığı, Ankara.

MEB (2018). *İlköğretim kurumları (ilkokullar ve ortaokullar) fen bilimleri dersi (3, 4, 5, 6, 7 ve 8. sınıflar) öğretim program [Primary schools (primary and secondary schools) science curriculum (grades 3, 4, 5, 6, 7 and 8)].* Talim ve Terbiye Kurulu Başkanlığı, Ankara.

MEB (2019). *Vizyon 2023 Belgesi [Vision 2023 Document].* Ankara.

Perry, V. R., & Richardson, C. P. (2001). *The new Mexico tech master of science teaching program: An exemplary model of inquiry-based learning*. 31st ASEE/IEEE Frontiers in Education Conference, Reno.

Silsüpür, T., & Bilican, K. (2021). Scaling of the self-efficacy of pre-service primary school teachers' in the courses on subject matter by Rank-order judgments, *The Journal of Turkish Educational Sciences, 1*(2), 98-114. https://doi.org/10.37217/tebd.1174140.

Smolleck, D. L., & Zembal-Saul, C. (2006). The development and validation of an instrument to measure preservice teachers'self-efficacy in regard to the teaching of science as inquiry, *Journal of Science Teacher Education, 17*(2):137-163. https://doi.org/10.1007/s10972-006-9015-6

Sümbüloğlu, K., & Sümbüloğlu, V. (2007). Biyoistatistik [Biyoistatistics]. Hatiboğlu Yayınevi.

Şahin, E., & Şeker, R. (2023). The impact of science teaching supported by concept cartoons on secondary school students' conceptual achievement, motivation and attitudes towards science, *Journal of Necmettin Erbakan University Ereğli Faculty of Education,* 5, 129-152. https://doi.org/10.51119/ereegf.2023.40.

Tatar, N., & Kuru, M. (2006). The effect of inquiry-based learning approach in science education on academic achivement, *Hacettepe University Journal of Education*, *31*(31), 147- 158.

Ünal, A. (2018). *Araştırma-sorgulamaya dayalı ve sosyal ağ destekli kimya laboratuvarı etkinliklerinin fen bilimleri öğretmen adaylarının algı, tutum ve başarıları üzerine etkisi [The effect of inquiry-based and social network supported chemistry laboratory activities on pre-service science teachers' perceptions, attitudes and achievements].* [Doctoral dissertation, University of Kastamonu].

Wood, W. B. (2003). Inquiry-based undergraduate teaching in life sciences at large research universities: A perspective on the boyer commision report. *Cell Biology Education,* 2, 112-116. https://doi.org/10.1187/cbe.03-02-0004.

Yaşar, Ş., & Duban, N. (2009). Students' opinions regarding to the inquiry-based learning approach, *Elementary Education Online, 8(*2), 457-475.

Yaman, S., Cansüngü Koray, Ö., & Altunçekiç, A. (2004). A research on the investigation of the self-sufficiency belief levels of the science education teacher candidates, *The Journal of Turkish Educational Sciences, 2*(3), 355-366.

Yılmaz, M., & Gürçay, D. (2011). Biyoloji ve Fizik öğretmen adaylarının öğretmen öz-yeterliklerini yordayan değişkenlerin belirlenmesi [Determination of variables predicting pre-service biology and physics teachers' teacher self-efficacy], *Cukurova University Faculty of Education Journal, 1*(40), 53-60.

Zacharia, Z. (2003). Beliefs, attitudes and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics, *Journal of Research in Science Teaching, 40* (8), 792-823. https://doi.org/10.1002/tea.10112.

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Primary School Teachers' Self-efficacy and Difficulties in Implementing STEAM Education

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Abstract

Recently, many countries around the world have paid more attention to the quality of natural and exact sciences, technology and engineering education – STEM disciplines have become extremely important in order to develop economic innovations. Educational research shows that successful integration of STEM requires content and pedagogical knowledge of these subjects, but teachers admit that they feel unprepared to apply STEM methodology. The subject and methodical, reflection and self-improvement competences of the primary school teacher are extremely important when the integration of STEAM subjects appears in the general education programs of many countries. The goal of the pilot study presented in this article is to validate in the Lithuanian sample the questionnaire designed to assess the difficulties of primary school teachers in teaching STEAM and to highlight their self-efficacy features. Statistical data analysis using SPSS 27 revealed the lack of self-efficacy of primary school teachers in teaching subjects related to the fields of chemistry and physics, which is one of the main reasons why teachers have difficulties in implementing STEAM activities. It is expected that the questionnaire will allow assess the professional development needs of primary school teachers and will help higher education institutions to improve teacher training programs.

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Introduction

In recent decades, the world has rapidly develope innovations in technology to meet the needs of sustainable energy and transportation, as well as environmental protection and effective healthcare. With the growing economic ambitions of world states, more attention has been paid to the quality of education in the fields of natural and exact sciences, technology and engineering. Understanding the nature of these sciences and the foundations of knowledge, i.e. STEM literacy, should become an educational priority for all students in the near future. On the other hand, educational researchers note that students lack some of these competencies: "The latest programme for international student assessment results, however, indicate that even in economically mature countries such as those in Europe, and the USA and Australia, approximately 20% of students lack sufficient skills in mathematics or science." (Maass, et al., 2019, p. 869).

Educators recognize that teacher competence determines the education quality and teacher understanding of the integration of STEM / STEAM subjects is an essential factor for its successful implementation (Widya, et al., 2019; Valtonen, et al., 2021). Teachers face a variety of challenges when integrate STEAM subjects. Lack of knowledge of STEAM subjects content and insufficient preparation for teaching these subjects are mentioned among the obstacles to the implementation of STEAM integration in practice (Belbase, et al., 2022; Cibulskaitė & Kurienė, 2015; Dignam, 2023; Hebebci, 2023; Saralar-Aras & Hebebci, 2023; Ling, et al., 2020; Spyropoulou & Kameas, 2020).

All the states that participate in the Bologna process join the unified European education space by creating study programs with the main focus on the education of teacher competencies: „Competence-based frameworks should be generalised to outline educators' development and career paths." (Learning and teaching. Final report. EHEA, 2024, p. 13). Therefore, when preparing pedagogical study programs, Lithuanian universities and colleges envisage the general and subject competencies of the pedagogic profession to be developed, the content of which is constructed taking into account the professional roles of the pedagogue, performed in the educational environment, i.e. pedagogical, organizational, interpersonal, etc. In the Lithuanian Description of competences of teachers and student support specialists (Mokytojų ir pagalbos mokiniui specialistų kompetencijų aprašas, 2023) pedagogue‘s competences are grouped into four competence areas: professional behaviour, cognitive, working together and emotional-motivational. The field of professional behavior includes the competencies of professional development, professional autonomy and reflection; the cognitive domain includes subject and interdisciplinary competence as well as the development and implementation of educational content. In this study, we name these competencies as reflection and self-improvement, subject and methodological.

Theoretical Background

The mentioned roles of teachers are based on the diffusion of various competences, of which a few can be singled out when provisions for the integration of STEAM subjects appear in the general education programs of many countries. These are subject and methodical competencies that guarantee transfer of the basics of the subject and understanding of the application of this subject in real life; as well as reflection and self-improvement competencies, guiding the teacher to take care of his personal and professional development. In the context of the modern continuous learning paradigm, the competencies of personal reflection are especially emphasized. Reflection is a process during which a person gets to know his states: through reflection, we get to know ourselves and our relationships with others; we look at the problem from different perspectives; we reflect on experiences, forms of activity and ways that lead to change and new knowledge. Reflection is one of the effective methods of continuous professional development - in the process of reflection, newly acquired professional experience is transformed into professional and personal development (Cibulskaitė, 2014).

The *goal of this research* is twofold: 1) to validate in the Lithuanian sample the questionnaire designed to assess the difficulties of primary school teachers in teaching STEAM related to subject and methodological competencies, and 2) to highlight the features of primary school teacher's self-efficacy, which is related to the competencies of reflection and self-improvement.

Method

Research method. The quantitative research carried out using the Teacher's efficacy scale questionnaire (TES), which developed by a group of researchers from several countries implementing the international Erasmus+ project ProSTEAM. The survey includes a scale to assess teachers' difficulties in teaching STEAM and a teacher self-efficacy scale. During the validation and pilot study of the questionnaire, primary school teachers answered the questions of the online survey and marked the answers on a 7-point Likert scale: from 1 - completely unsure to 7 - completely sure. Statistical analysis of the collected data performed using SPSS 27 (Garson, 2013a; 2013b).

Instrument. In cooperation with the ProSTEAM team, the first version of TES in English was prepared. It presented to four Lithuania primary school teachers who know English good enough. Teachers were asked to answer each question by ticking the appropriate scale score and to explain why they chose one or another score. When answering questions, teachers translated them into Lithuanian, and this made it possible to make sure that they understood all questions adequately. In order to improve the questionnaire, teachers' comments and summaries of their interviews are provided. Then a group of three experts used a back-to-back translation procedure, all experts translated the original version of TES into Lithuanian, these translations were compared with each other and the final Lithuanian version of TES was constructed. Some questions were a little bit adjusted to match the context of Lithuanian education and the national thesaurus of pedagogy: more precise words were chosen for the wording; it was achieved that similar questions about different teaching subjects use the same terms; names of rating scale scores have been clarified.

Model. The expert team estimated the factor structure and tested several competing models in order to find which one had the more acceptable fit. The team identified three models that might be reliable and suggested that project participants test the reliability of the ten-factor system using national data. After factor analysis and internal validity testing, the TES questionnaire consisted of 52 items. The results showed that Lithuanian data (Table 1) are similar to other three project participants collected data and correspond to the general average.

Table 1. Overview of Fit Indices for Three Factor Solutions (Lithuania data, N = 118)

Models	**χ2**	**df**	**CFI**	**TLI**	**RMSEA**	**RMSEA 95% CI**
MODEL 1: 8 factors	1764.1***	1246	0.971	0.969	0.059	].053; .066[
MODEL 2: 9 factors	1741.3***	1238	0.972	0.970	0.059	].052; .065[
MODEL 3: 10 factors	1678.8***	1229	0.975	0.973	0.056	].049; .062[

***$p < .001$

The characteristics of the variables that make up all the factors are quite close: for both mean values and standard deviations. Differences established between symmetry or asymmetry of distributions of variables and their kurtosis. As an example of calculations, the results of statistical analysis for Factor1 are presented in Table 2 and Table 3.

Table 2. Calculation of Variables Statistics for Factor1 (N = 118)

Variables	**TIG1**	**TIG2**	**TIG3**	**TIG4**
Valid	118	118	118	118
Missing	0	0	0	0
Mean	5.35	5.62	5.71	5.55
Std. Deviation	1.355	1.085	1.047	.992
Skewness	-1.139	-1.229	-1.261	-,971
Std. Error of Skewness	.223	.223	.223	.223
Kurtosis	1.687	2.810	3.497	2.961
Std. Error of Kurtosis	.442	.442	.442	.442

Table 3. Calculation of Variables Correlation for Factor1 (N = 118)

Variables		**TIG1**	**TIG2**	**TIG3**	**TIG4**
TIG1	Pearson Correlation	1	.742**	.577**	.677**
	Sig. (2-tailed)		.000	.000	.000
	N	118	118	118	118
TIG2	Pearson Correlation	.742**	1	.760**	.776**
	Sig. (2-tailed)	.000		.000	.000
	N	118	118	118	118
TIG3	Pearson Correlation	.577**	.760**	1	.788**
	Sig. (2-tailed)	.000	.000		.000
	N	118	118	118	118
TIG4	Pearson Correlation	.677**	.776**	.788**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	118	118	118	118

** Correlation is significant at the 0.01 level (2-tailed)

The third 10-factor model selected for use in the research, because the results of statistical analysis of all factors variables showed:

(a) the means of the variables within all the factors except F5 and F10 are more than 5.0 and less than 5.8; the means of the factors of F5 and F10 are more than 4.0 and less than 4.7;

(b) distributions of the variables within factors F1 and F4 are more asymmetrical than symmetrical, within factors F2, F3, F6, F7, F8, and F9 - more symmetrical than asymmetrical; factors F5 and F10 have all symmetrical distributions of the variables; these results indicate the similarity of all distributions to the normal distribution;

(c) the all distributions of variables of F1, F4, F6, F9 have sharp peaks, F3 have 5 peaks and F8 - 6 peaks – this indicates that these data are not scattered; the distribution of all variables of F5 and F10 are flat, F2 and F7 are almost flat, but have 1 or 2 peaks – this indicates that these data are more or less scattered;

(d) the correlations between all the variables are strong or moderate within all the factors except F2, there a weak positive correlation of three variables is observed - this indicate that there is a correlation, but not as strong as for the other factors variables; the all correlations are statistically significant;

(e) the shapes of the variable distributions of factors F5 and F10 are similar to each other, the mean values and standard deviations are close, which means that these factors are very similar in their characteristics; the similarity of the characteristics of the remaining factors cannot be stated unequivocally.

Participants. The sample of respondents consists of 118 elementary school teachers of 61 "STEAM school label" schools coordinated by the National Education Agency of the Republic of Lithuania. The school can get this label if integrated STEM education ideas implemented in the educational process and teachers with students actively participated in STEAM projects, concourses and actions across the country and abroad. The research sample represents all counties of the country. Two teachers from each school filled out the questionnaire; no answers received from two schools, so the level of non-response is only 3.3%. The number and percentages of teachers in each demographic characteristic presented in Tables 4 and 5.

Table 4. Demographic Characteristics of Respondents for Gender, Education, and Training (Frequency in %)

Demographic characteristics		**N**	**%**
Gender	Female	118	100
Level of formal education completed	Bachelor's or equivalent level	86	72.9
	Degree or equivalent level	1	0.9
	Master's or equivalent level	28	23.7
	Doctor or equivalent level	3	2.5
Training in STEAM	Yes	58	49.2
Training in integrated teaching	Yes	56	47.5

All respondents were female, the average age of the participants is 50 years, and average teaching experience is 25 years, the teaching experience at the same school - 16 years. 73.8 % of the study participants have a bachelor or equivalent degree; 23.7% had a master degree, and a few had a doctorate (2.5%).

A half of the informants (49.2%) claim to have participated in various STEAM competence development events (for example, STEAM education for leadership, Technological STEAM solutions, Small technology developers, STEAM lesson for little ones, Technology and engineering in primary grades), carried out projects, visited laboratories of STEAM centers, learned to use ICT platforms related to STEAM. Slightly less than half of the informants (47.5 %) noted that they constantly improve their qualifications in integrated teaching at conferences and seminars (for example, Education in non-traditional environments, Blended learning, Thinking school methods, Creative programming), participated in Erasmus+ projects, etc.

Table 5. Descriptive Statistics of Demographic Characteristics for Age and Teaching Experience

Demographic characteristics	**M**	**SD**	**Min**	**Max**
Age (years)	49.7	8.9	23	65
Teaching Experience	24.8	11.5	1	43
Teaching experience in current school	15.9	12.9	0	43

Results

Statistical Analysis for the Factors

The means, standard deviations, skewness and kurtosis, and normality test were calculated for all the factors (Table 6, Table 7).

Table 6. Descriptive Statistics, Mean, SD, Skewness and Kurtosis and Reliability Scores of the Dimensions

Dimensions	**N**	**Mean**	**Std. Dev.**	**Skewness**		**Kurtosis**	
				Statistic	Std. Error	Statistic	Std. Error
Teaching in General - I	118	5.557	.993	-1.108	.223	3,210	,442
Teaching in General - BM	118	5.524	.782	-.414	.223	.677	.442
Math & Math Motivation	118	5.467	.861	-.537	.223	.452	.442
Biology Teaching	118	5.271	1.217	-1.177	.223	2.023	.442
Chemistry Teaching	118	4.377	1.333	-.367	.223	.034	.442
Science Motivation	118	5.155	.990	-.889	.223	2.828	.442
Arts & Arts Motivation	118	5.260	.994	-.758	.223	1.806	.442
ICT Use	118	5.421	1.051	-.817	.225	1.599	.446
Physics Teaching	118	5.261	1.088	-.878	.225	1.449	.446
Integrated Teaching	118	4.468	1.326	-.537	.223	.254	.442
Valid N (listwise)	118						

Note: Teaching in General - I = Teaching in General - Instruction; Teaching in General - BM = Teaching in General - Behavior Management; Math & Math Motivation = Math Teaching and Math Motivation; Arts & Arts Motivation = Arts Teaching and Arts Motivation; ICT Use = Information and Communications Technology Use.

Statistical analysis for the factors let us to state:

(a) the mean values of almost all factors are quite close, two factors F5 and F10 stand out quite clearly – the means of F5 and F10 are more than 4.3 and less than 4.5; the average values of other factors are more than 5.1 and less than 5.6; meanwhile, the standard deviations are not very different and their values are close to 1;

(b) the distributions of the factors are not characterized by pronounced asymmetry - skewness is < -1 only for a couple of factors F1 and F4;

(c) as for a kurtosis, we can see that most of the factor (F1, F4, F6, F7, F8, F9) distributions have sharper - more pointed peaks (index >1), others four (F2, F3, F5, F10) are more flat, this means that these data are more scattered;

(d) the Kolmogorov-Smirnov test shows that the distributions of all factor variables cannot be considered normal, however, for the factors we form from those variables, normality is present (only F4 is questionable, Sig. 0.006), it allows the application of parametric criteria.

Table 7. One - Sample Kolmogorov-Smirnov Test

Variables	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**
N	118	118	118	118	118	118	118	118	118	118
Normal Parameters a, b Mean	5.557	5.524	5.467	5.271	4.377	5.155	5.260	5.421	5.261	4.468
Std. Deviation	.993	.782	.861	1.217	1.333	.991	.994	1.051	1.088	1.326
Most Extr. Differ. Absolute	.121	.073	.098	.158	.102	.124	.075	.103	.112	.113
Positive	.090	.063	.065	.078	.061	.087	.041	.067	.076	.065
Negative	-.121	-.073	-.098	-.158	-.102	-.124	-.075	-.103	-.112	-.113
Kolmogorov-Smirnov Z	1.315	.798	1.066	1.712	1.104	1.351	.815	1.108	1.208	1.232
Asymp. Sig. (2-tailed)	.063	.547	.205	.006	.174	.052	.520	.171	.108	.096

a. Test distribution is Normal b. Calculated from data.

Correlation among the Factors

Data shows, all ten factors significantly and positively correlated with each other (Table 8). The correlation is strong (> 0.7) among: F1- F2, F3, F6; F2- F3, F6; F3 - F4, F6; F4 - F5, F6, F9, F10; F5 - F6, F10; F6 - F10. The correlation is medium (0.5 - 0.7) among other factors, except F5 - F7, F8, and F7 - F10, which correlation is weak (0.3 - 0.5) (Garson, 2013).

Table 8. Correlations among the Factors

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**
F2	0.857								
F3	0.880	0.819							
F4	0.676	0.674	0.713						
F5	0.514	0.505	0.598	0.764					
F6	0.745	0.791	0.836	0.802	0.703				
F7	0.662	0.630	0.620	0.607	0.435	0.675			
F8	0.621	0.658	0.511	0.608	0.396	0.642	0.599		
F9	0.551	0.650	0.583	0.724	0.637	0.691	0.539	0.640	
F10	0.589	0.543	0.647	0.759	0.848	0.767	0.481	0.540	0.689

Note: F1= Teaching in General - Instruction; F2 = Teaching in General - Behavior Management; F3 = Math Teaching; F4 = Biology Teaching; F5 = Chemistry Teaching; F6 = Science Motivation; F7 = Arts Teaching; F8 = ICT Use; F9 = Integrated Teaching; F10 = Physics Teaching. All correlations were significant at $p < 0.01$.

To assess internal consistency, Cronbach's alpha coefficient calculated, the reliability analyzed for the variables that make up each factor (Table 9). Both unstandardized and standardized Cronbach's alpha values for all factors are greater than 0.9, except the Factor2, which value is less than 0.9, however, that shows very good compatibility of all factors variables. Sufficiently strong multi-factor correlation and good internal validity of the scale let us state: the all variables within all factors are aligned or homogeneous in terms of measurement scale; the variances of the responses to individual questions are quite similar; the scale is valid, it measures the intended variables very well.

Table 9. Cronbach's Coefficient Alpha for the Scale Dimensions

Dimensions	Number of items	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items
Teaching in General - Instruction	4	.903	.911
Teaching in General - Behavior Management	5	. 865	.865
Math Teaching and Math Motivation	8	.933	.934
Biology Teaching	4	.954	.954
Chemistry Teaching	4	.918	.919
Science Motivation	4	.919	.919
Arts & Arts Motivation	8	.951	.951
ICT Use	7	.937	.938
Physics Teaching	4	.912	.912
Integrated Teaching	4	.936	.936

The Groups of the Factors

The picture of the all factors means and their 95% confidence intervals shows a clear separation of the factors F5 and F10 and the possibilities of two more interrelated groups of factors (Figure 1).

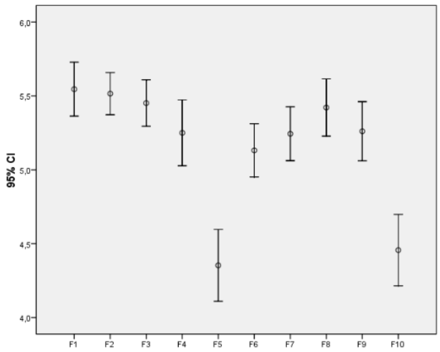

Figure 1. The Factors Mean and Their Confidence Intervals (95%)

The results of statistical analysis made it possible to distinguish groups of interrelated factors: first group consist of factors F1, F2, F3 and F8; second group – of factors F4, F6, F7 and F9; and third group – of F5 and F10. ANOVA analysis made for the first and second groups, and t-test for the third group (Table 10 - Table 15).

Table 10. ANOVA Analysis for the Group of Factors F1, F2, F3, F8

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.275	3	.425	.494	.686
Within Groups	400.499	466	.859		
Total	401.773	469			

$p > 0.05$

Table 11. Multiple Comparisons (Bonferroni) for the Group of Factors F1, F2, F3, F8

(I) factor	(J) factor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.03347	.12069	1.000	-.2863	.3533
	3.00	.09004	.12069	1.000	-.2297	.4098
	8.00	.13602	.12121	1.000	-.1851	.4572
2.00	1.00	.03347	.12069	1.000	-.3533	.2863
	3.00	.05657	.12069	1.000	-.2632	.3764
	8.00	.10255	.12121	1,000	-.2186	.4237
3.00	1.00	-.09004	.12069	1.000	-.4098	.2297
	2.00	-.05657	.12069	1.000	-.3764	.2632
	8.00	.04598	.12121	1.000	-.2752	.3671
8.00	1.00	-.13602	.12121	1.000	-.4572	.1851
	2.00	-.10255	.12121	1,000	-.4237	.2186
	3.00	-.04598	.12121	1.000	-.3671	.2752

Table 12. ANOVA Analysis for the Group of Factors F4, F6, F7, F9

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.063	3	.354	.306	.821
Within Groups	539.772	466	1.158		
Total	540.835	469			

$p > 0.05$

Table 13. Multiple Comparisons (Bonferroni) for the Group of Factors F4, F6, F7, F9

(I) factor	(J) factor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
4.00	6.00	.11653	.14012	1.000	-.2547	.4878
	7.00	.01165	.14012	1.000	-.3596	.3829
	9.00	.01041	.14072	1.000	-.3624	.3833
6.00	4.00	-.11653	.14012	1.000	-.4878	.2547
	7.00	-.10487	.14012	1.000	-.4761	.2664
	9.00	-.10611	.14012	1.000	-.4790	.2667
7.00	4.00	-.01165	.14012	1.000	-.3829	.3596
	6.00	.10487	.14012	1.000	-.2664	.4761
	9.00	-.00124	.14012	1.000	-.3741	.3716
9.00	4.00	-.01041	.14012	1.000	-.3833	.3624
	6.00	.10611	.14012	1.000	-.2667	.4790
	7.00	.00124	.14012	1.000	-.3716	.3741

Table 14. T-test Group Statistics for the Group Pair of Factors F5, F10

Factor	N	Mean	Std. Deviation	Std. Error Mean
5.00	118	4.3771	1.33323	.12273
10.00	118	4.4682	1.32632	.12210

Table 15. Independent Sample Test for the Pair of Factors F5, F10

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
Equal variances:	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
assumed	.018	.895	-.526	234	.599	-.09110	.17312	-.43218	.24998
not assumed			-.526	233.994	.599	-.09110	.17312	-.43218	.24998

p > 0.05

The ANOVA analysis and t-test confirmed the hypotheses about the statistically significant equality of the means of factor groups: (a) checked equality of means with parametric criteria shows that the means of factors F1, F2, F3 and F8 are not statistically significantly different (Sig. 0.686, p > 0,05); (b) analogously, the means of factors F4, F6, F7 and F9 do not differ statistically significantly (Sig. 0.821, p > 0,05); (c) factors F5 and

F10 – the t-test for two independent samples shows that the means of this factors can be considered equal (Sig. 0.599, p > 0,05). The results allow us to assert that when answering the questions of the identified groups of factors, teachers choose similar answer options (scores).

The Characterization of Lithuania Primary School Teachers in Relation to Their Self-efficacy in Teaching STEAM

The characteristics of questioned Lithuanian primary school teachers in terms of their self-efficacy were carried out based on their level of education, learning STEAM and PBL, teaching experience in general and in the school where they currently work. In determining whether the level of self-efficacy of teachers differs depending on the acquired education (Figure 2), it was found that teachers with bachelor's and licentiate degree education are much less self-efficacy than teachers with a higher master's or doctoral degree in all teaching areas.

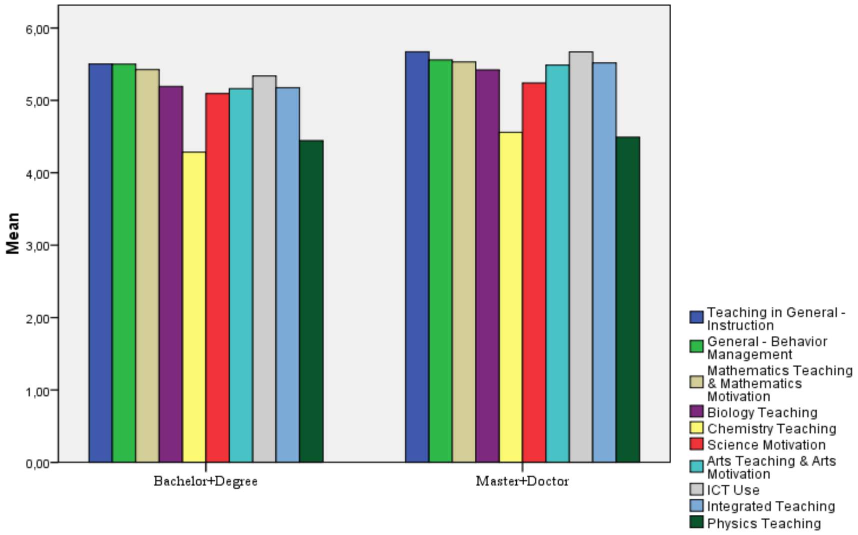

Figure 2. Means of the Dimensions in Relation to the Variable "Level of Education"

Examining the self-efficacy of teachers depending on whether they had STEAM training or not (Figure 3), it can be state that:

(a) the teachers of both acquired education groups have similar and least self-efficacy in the subject area of chemistry;

(b) the level of self-confidence of untrained teachers in chemistry and physics is almost the same and the lowest, in this case trained teachers in the field of physics feel more confident than in chemistry;

(c) the trained teachers are more self-confident than untrained teachers in all tested areas.

Examining the results of the analysis according to the variable "Training in integrated approaches to teaching", it was observed that these results are almost the same as those discussed above according to the variable "Training in STEAM" (Figure 4), except that the level of self-confidence of untrained teachers in the field of physics is slightly higher than in the field of chemistry.

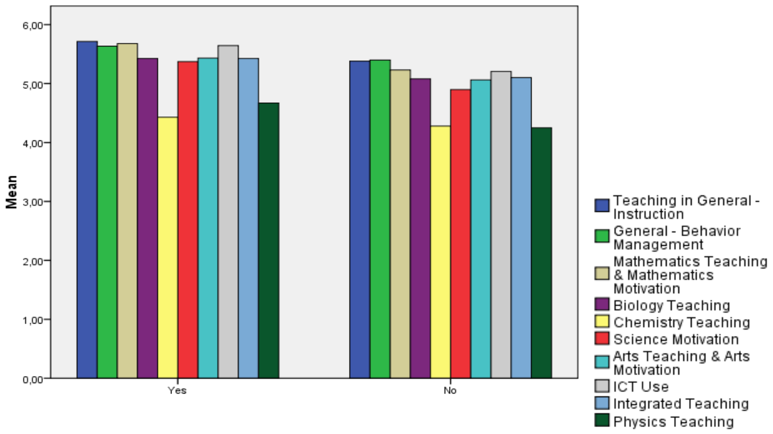

Figure 3. Means of the Dimensions in Relation to the Variable "Training in STEAM"

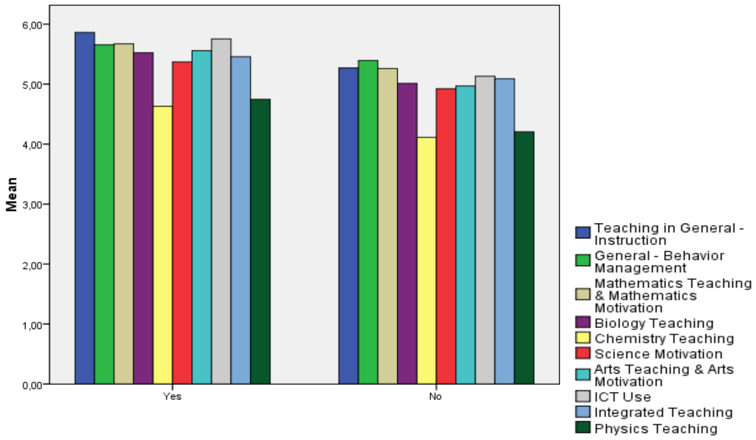

Figure 4. Means of the Dimensions in Relation to the Variable "Training in Integrated Approaches to Teaching"

Teachers of different groups of teaching experience demonstrate the highest and higher level of self-confidence as follows (Figure 5):

(a) the first group ($n \leq 10$) – Communications Technology Use, Teaching in General - Instruction and Behavior Management, Arts & Arts Motivation;

(b) the second group ($10 < n \leq 20$) – Communications Technology Use, Teaching in General - Instruction, Math Teaching and Math Motivation, Arts & Arts Motivation;

(c) the third group (20 <n ≤30) – Teaching in General - Instruction and Behavior Management, Math Teaching and Math Motivation, Integrated teaching;

(d) the fourth group (n > 30) – Teaching in General - Instruction and Behavior Management, Math Teaching and Math Motivation, Biology Teaching.

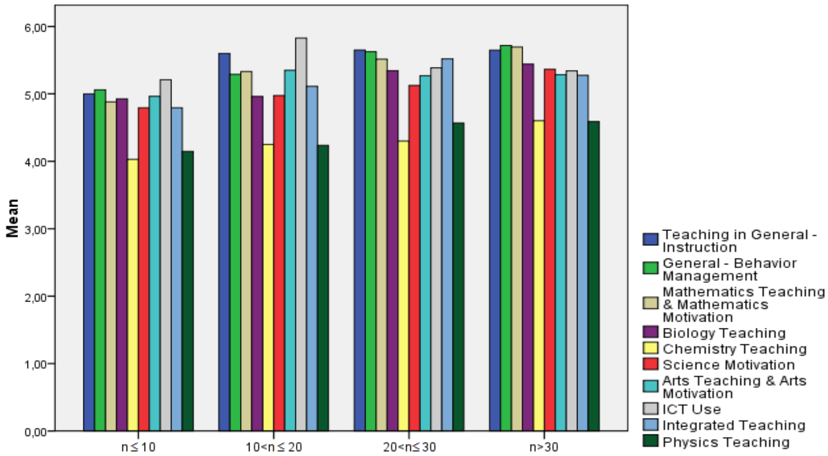

Figure 5. Means of the Dimensions in Relation to the Variable "Teaching Experience"

Consequently, teachers with up to 20 years of practice feel they have better mastered Communications Technology Use and Arts & Arts Motivation, as well as being knowledgeable about Teaching in General. It can be assumed that less experienced and probably younger teachers are more proficient ICT users and have acquired modern theoretical knowledge of pedagogy. Those who have been working in a school for more than 20 years are more confident in applying Teaching in General strategies, as well as in teaching mathematics and biology. It can be assumed that more practice leads to greater self-confidence in the application of knowledge of pedagogy and methodology and in the teaching of mathematics and biology subjects.

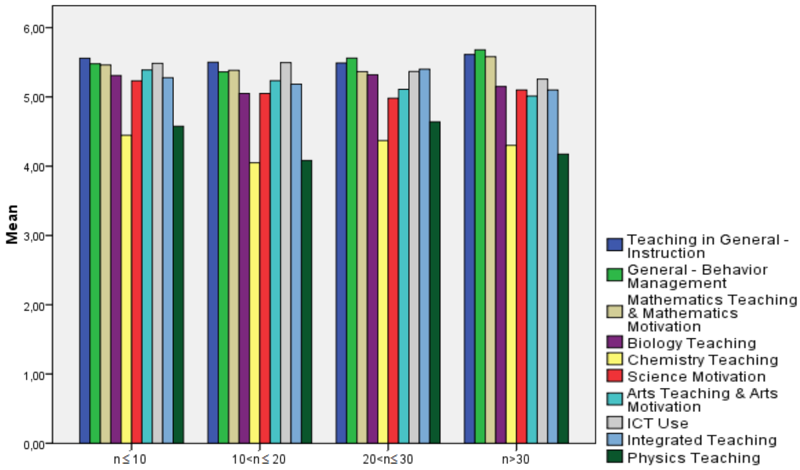

Figure 6. Means of the Dimensions in Relation to the Variable "Teaching Experience in the Same School"

The teachers of all groups have the least self-confidence in the fields of teaching chemistry and physics. It was found that self-efficacy for Teaching in General (Instruction and Behavior Management), Math Teaching and Math Motivation, Biology Teaching and Science Motivation increased with increasing years of experience; this tendency is observed in Chemistry and Physics Teaching as well. Self-motivation in Integrated teaching arises until teachers accumulate 30 years of experience, in teaching Arts – until 20 years of experience.

The same four groups created to study the variable “Teaching Experience in the same School” (Figure 6). It was found that all teachers are similar more confident in Teaching in General – Instruction and Behavior Management, Math Teaching and Math Motivation; less experienced teachers demonstrated stronger self-efficacy in ICT use and Arts & Arts Motivation area than more experienced teachers.

Conclusion

The integration of STEM subjects requires teachers’ knowledge of these subjects content and pedagogical content knowledge on how to convey this content to students, however according to educational researches, primary school teachers admit that they feel unprepared to apply a specific STEM methodology.

The Teacher's efficacy scale questionnaire allows assessing the teacher's self-efficacy in STEAM education: its application in the Lithuanian sample showed appropriate psychometric properties; strong multifactor correlation and good internal validity indicated the reliability of the scale.

It was found that less experienced younger teachers are more proficient ICT users and have acquired modern theoretical knowledge of pedagogy, but more practice leads to greater self-efficacy in the use of methodology knowledge and in the teaching of math and biology. This may testify to the importance of university second-cycle primary teacher training in order to prepare qualified educators in STEAM education.

In STEAM education trained teachers are more self-efficacy than untrained and more experienced teachers. This substantiates the importance of STEAM education qualification training, which means that greater attention is required to pay for the continuous training of in-service teachers, especially in the field of integrated education.

The study highlighted the lack of self-efficacy in the subject area of chemistry and physics teaching among primary school teachers who have a higher level of education, who seek to improve their qualifications, and who have more teaching experience. Primary school teacher training institutions aiming to prepare teachers who meet the needs of STEAM education should improve their study programs by including content study modules in these subjects.

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References

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., & Jarrah, A. (2022). At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: Prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*, *53*(11), 2919–2955.

Cibulskaitė N. (2014). *Pedagoginė praktika – mokytojo profesiniam tapsmui*. Vilnius: LEU.

Cibulskaitė N., & Kurienė A. (2015). Būsimųjų gamtos mokslų ir matematikos mokytojų integracinių ryšių taikymo gebėjimų ugdymas(is). *Pedagogika, 1*(117), 133–142.

Dignam, C. (2023). Canvases of Professional Erudition in STEAM Education. *International Journal of Academic Studies in Science and Education*, *1*(1), 1–21. https://doi.org/10.55549/ijasse.3

Garson G.D. (2013a). *Factor analysis*. Statistical Associates Publishers.

Garson G.D. (2013b). *Validity and Reliability*. Statistical Associates Publishers.

Ling, L. S., Pang, V., & Lajium, D. (2020). A Case study of teachers' pedagogical content knowledge in the implementation of integrated STEM education. *Journal Pendidikan Sains Dan Matematik Malaysia*, *10*(1), 49–64.

LRS, (2023). Mokytojų ir pagalbos mokiniui specialistų kompetencijų aprašas. https://e-seimas.lrs.lt/portal/legalAct/lt/TAP/c5a8c4d15de511ee8e3cc6ee348ebf6d?jfwid=-o1nifns2r

Maass, K., Geiger, V., Ariza, M. R., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *Zdm*, *51*, 869–884.

Saralar-Aras, İ., & Hebebci, M. T. (2023). Designing an engaging STEM activity with integrated assessment tools for middle school mathematics. In C. Dignam (Ed.) Proceedings of International Conference on Academic Studies in Science and Education 2023, (pp. 1-8). Istanbul, Turkey. ARSTE

Spyropoulou, N. D., & Kameas, A. D. (2020). STEM Educator challenges and professional development needs: the educators' views. In *2020 IEEE Global Engineering Education Conference (EDUCON)* (p. 554–562). IEEE.

The European Higher Education Area [EHEA] (2024) *Learning and teaching. Final report*. https://ehea.info/Immagini/Learning-and-Teaching-Final-Version.pdf

Valtonen, T., Hoang, N., Sointu, E., Näykki, P., Virtanen, A., Pöysä-Tarhonen, J., Häkkinen, P., Järvelä, S., Mäkitalo, K., & Kukkonen, J. (2021). How pre-service teachers perceive their 21st-century skills and dispositions: A longitudinal perspective. *Computers in Human Behaviour, 116*, Article 106643. https://doi.org/10.1016/j.chb.2020.106643

Widya W., Rifandi, R., & Rahmi, Y. L. (2019). STEM education to fulfill the 21st century demand: a literature Review. *Journal of Physics: Conference Series, 1317*(1), Article 012208.

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The Effect of Some Variables on Mathematical Resilience: A Regression Model

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Abstract

In the present study, it was aimed to determine the power of mathematics belief, and epistemological belief to predict mathematical resilience. Relational survey model was used in the research conducted with quantitative paradigm. The sample of the research consists of pre-service teachers. "Mathematical Resilience Scale", "Epistemological Beliefs Scale", and "Mathematics Beliefs Scale" were used as measurement tools. Regression analysis was performed to find answers to the research questions. Four different models were tested in the study. As a result, mathematics belief, and epistemological belief were found to be significant predictors of mathematical resilience. In addition, the factors of belief that learning depends on ability, belief that learning depends on effort, and usefulness were found to have high predictive power for mathematical resilience. Accordingly, as a result of the study, it is suggested that pre-service teachers should develop positive attitudes towards mathematics and have high levels of epistemological beliefs in order to develop mathematical resilience. In addition, it is suggested that pre-service teachers' developing beliefs that learning mathematics requires effort, that mathematics is useful, and that learning mathematics is related to ability will positively affect their mathematical resilience levels.

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Introduction

Mathematics is generally seen as an area that arouses feelings such as fear, anxiety, and panic among individuals, and is difficult to study. Mathematical resilience enables students to protect themselves from feelings of anxiety, fear or learned helplessness that may arise when learning mathematics becomes difficult, and to manage these feelings (Lee & Johnston-Wilder, 2017). Mathematical resilience is a conceptual construct introduced to represent a positive attitude towards mathematics (Johnston-Wilder & Lee, 2010a). In this context, when we face a mathematical challenge, our ability to overcome the challenge is related to our mathematical resilience. Individuals with mathematical resilience have four basic characteristics: Growth mindset, value, knowing how to work in mathematics, knowing how to recruit support (see Figure 1) (Johnston-Wilder et al., 2014).

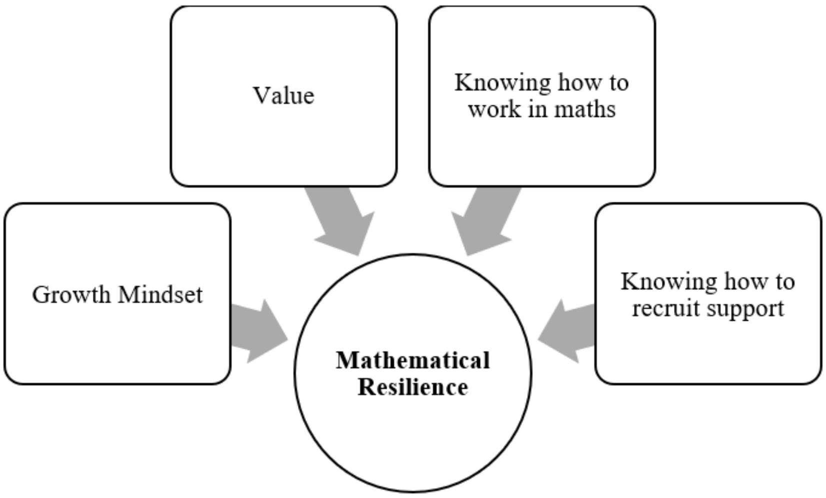


Figure 1. Four Basic Characteristics of Individuals with Mathematical Resilience

The growth mindset dimension is based on the idea that an individual's brain capacity can grow. Brain capacity is not fixed and can grow (Johnston-Wilder et al., 2014). Regardless of the capacity of the individual, it is possible to achieve success in mathematics when the individual shows the necessary dedication (Lee & Johnston-Wilder, 2013). The value dimension is generally related to seeing mathematics as a valuable field and consists of two sub-dimensions; the first one is understanding the value of mathematics (Lee & Johnston-Wilder, 2015; Johnston-Wilder et al., 2013) and the other one is seeing oneself as a valuable part of the mathematical community (Lee & Johnston-Wilder, 2017). Both situations are related to the value the individual places on mathematics. The dimension of knowing how to work in mathematics, as the name suggests, is related to how students can work in mathematics. Anyone dealing with mathematical problems may make mistakes or encounter difficulties. What is important is the reaction to them. Students with mathematical resilience know that they need to struggle and persevere when faced with these difficulties and errors (Lee &

Johnston-Wilder, 2015). The dimension of knowing how to get support is related to students' knowledge about where and how they can get support when they encounter difficulties. That is, the student knows how to get support from peers, teachers, other adults, books, information, and communication technologies (ICT), the Internet, etc. to support mathematical learning (Johnston-Wilder et al., 2013).

The resilience required to learn mathematics has a particular structure because of several factors (Johnston-Wilder & Lee, 2010b), such as the type of teaching used (Nardi & Steward, 2003), the nature of mathematics and widespread beliefs that mathematical ability is “fixed” (Dweck, 2010, Lee, 2006). To determine students' mathematical resilience, it is important to identify the factors affecting mathematical resilience. In this sense, it will be possible to ensure the development of students' mathematical resilience; making changes in the sub-factors that directly affect mathematical resilience and strengthening these aspects of the student will contribute to the development of mathematical resilience. However, there are no model development studies in the literature that will enable us to predict mathematical resilience. The present study takes an important step towards filling this gap in literature. The research is a strong and original study in this respect.

The theory of mathematical resilience is based on the idea that anyone can achieve success in mathematics when the necessary effort is made. Individuals with mathematical resilience are expected to have high belief towards mathematics and science and it is thought that these two conceptual structures will contribute to the prediction of mathematical resilience. There are no studies in literature examining the relationship between these factors and mathematical resilience. Therefore, in order to determine mathematical resilience, it is important to determine the power of belief towards mathematics and/or beliefs about knowledge to predict mathematical resilience. For this reason, the present study aimed to determine the predictive power of the concepts of mathematics belief and epistemological belief on mathematical resilience. In line with this purpose, an answer to the question "What is the predictive power of mathematics belief and epistemological belief factors for mathematical resilience?" is sought. The sub-problems of the research are as follows:

1. What is the predictive power of mathematics belief on mathematical resilience?
2. What is the predictive power of epistemological belief on mathematical resilience?
3. What is the predictive power of mathematics belief and epistemological belief together on mathematical resilience?
4. What is the predictive power of mathematics belief and epistemological belief sub-dimensions on mathematical resilience?

Method

Research Design

The present study was designed in accordance with the survey model based on the quantitative paradigm. The survey model is a quantitative description of the universe through research conducted on the sample (Cresswell, 2012). In the survey model, the event, individual or object that is the subject of the research is described within its own conditions without any change. The researcher does not endeavor to influence or change the relevant subject (Karasar, 2006). In the present study, relational screening model was used to determine the relationship between variables. The research is predictive relational research since it examines the power of different variables to predict a variable by examining the relationship between variables. In the predictive procedure, starting from a known value of a variable, the unknown value of another variable is tried to be determined (Büyüköztürk et al., 2017).

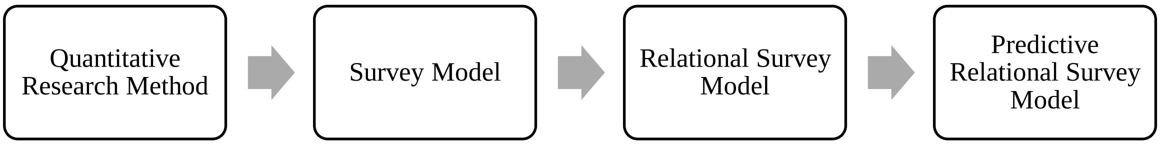


Figure 2. Scheme of Research Design

Participants

The study group of the research consists of 259 pre-service teachers (207 females and 52 males) studying in the department of elementary mathematics teaching at universities in the Central Anatolia Region in the 2021-2022 academic year. In the selection of the sample, convenience sampling was preferred. Convenience sampling saves time and money. It also saves the researcher the effort of finding less suitable participants (Cohen et al., 2007). The distribution of the participants according to grade level is as follows: 58 (48 female and 10 male) 1st grade students, 86 (70 female and 16 male) 2nd grade students, 62 (49 female and 13 male) 3rd grade students, and 53 (40 female and 13 male) 4th grade students (see Table 1). The pre-service teachers participated in the study voluntarily.

Table 1. Distribution of Participants

	1st grade students	2nd grade students	3rd grade students	4th grade students	Total
Female	48	70	49	40	207
Male	10	16	13	13	52
Total	58	86	62	53	259

Data Collection Tools

The data collection tools used in the study are 'Mathematical Resilience Scale', 'Epistemological Beliefs Scale', and 'Mathematics Beliefs Scale'. The Mathematical Resilience Scale developed by Kooken et al. (2016) was used to determine pre-service teachers' mathematical resilience. Gürefe and Akçakalın (2018) adapted this scale for Turkish university students and conducted a validity-reliability study. This study was conducted on 834 undergraduate students studying at the faculties of education and engineering of a university located in the Aegean Region of Türkiye. While the original form of the mathematical resilience scale consists of 24 items, the form adapted to Turkish culture includes 19 items. During adaptation, 5 items with low factor loadings were removed from the original form. The mathematical resilience scale consists of three factors: Value, Struggle, and Growth. The scale is a 7-point Likert-type scale ranging from (1) strongly disagree to (7) strongly agree. The reliability coefficients of the dimensions in the original scale vary between 0.73 and 0.94 (Kooken et al., 2016). The Cronbach Alpha internal consistency coefficients of the adapted scale were calculated as 0.92 for the first factor, 0.80 for the second factor, 0.76 for the third factor, and 0.87 for the whole scale (Gürefe & Akçakalın, 2018). The Cronbach Alpha internal consistency coefficients calculated in the current study were 0.88 for the first factor, 0.81 for the second factor, 0.84 for the third factor, and 0.81 for the whole scale.

The Epistemological Belief Scale developed by Schommer (1990) was used to determine pre-service teachers' epistemological beliefs. The adaptation of this scale on Turkish university students was conducted by Deryakulu and Büyüköztürk (2002). This study was conducted on 595 undergraduate students studying in various departments of education, communication, science-literature and engineering faculties of universities in Ankara. The scale consists of 35 items. In its original form, the scale consisted of 4 sub-dimensions, but when it was adapted to Türkiye, due to cultural differences, it consisted of three dimensions: "belief that learning depends on effort", "belief that learning depends on ability", and "belief that there is only one truth". The scale is a 5-point Likert-type scale ranging from (1) strongly disagree to (5) strongly agree. The reliability coefficients of the dimensions in the original scale vary between 0.63 and 0.85 (Schommer, 1993). Cronbach Alpha internal consistency coefficients of the adapted scale were calculated as 0.83 for the first factor, 0.62 for the second factor, 0.59 for the third factor, and 0.71 for the whole scale (Deryakulu & Büyüköztürk, 2002). The Cronbach Alpha internal consistency coefficients calculated in the current study were 0.82 for the first factor, 0.81 for the second factor, 0.75 for the third factor, and 0.81 for the whole scale.

The Mathematics Belief Scale developed by Steiner (2007) was used to determine pre-service teachers' beliefs about mathematics. Masal and Takunyacı (2012) adapted this scale for Turkish university students and conducted a validity and reliability study. The scale consists of 34 items and five factors: Time, Steps, Understanding, Usefulness, and Sense of Self. The scale is a 5-point Likert-type scale ranging from (1) strongly disagree to (5) strongly agree. The reliability coefficients of the dimensions in the original scale vary between 0.71 and 0.91 (Steiner, 2007). The Cronbach Alpha internal consistency coefficient of the adapted scale was calculated as 0.87 and the reliability coefficient obtained by the split-half method was calculated as 0.92 (Masal & Takunyacı, 2012). The Cronbach Alpha internal consistency coefficient calculated in the current study was 0.87.

Data Analysis

Regression analysis was performed to determine the predictive power of the independent variables for the dependent variable. If the number of independent variables is one, a linear regression model is used and if the number of independent variables is two or more, a multiple linear regression model is used. With this statistic, it is determined which of the independent variables affects the value of the dependent variable more (Alpar, 2011).

In multiple linear regression analysis, all independent variables may not significantly predict the dependent variable. Forward selection method, backward selection method, and stepwise selection methods can be used to make the model meaningful (Kayaalp et al., 2015). The backward selection method is one of the most basic and widely used feature selection algorithms available (Borboudakis & Tsamardinos, 2019). Therefore, a backward selection method is used in this study. This method starts with all available variables and then removes unnecessary variables step by step until some stopping criteria are met (Borboudakis & Tsamardinos, 2019; Pierna et al., 2009). First, all variables are included in the model. Then, the independent variables with the least contribution to the model are identified and removed from the model sequentially, one variable at each stage. When each variable is removed, the contribution of the removed variable to the model is analyzed.

Ethics Committee Approval

In line with the decision of Necmettin Erbakan University Ethics Committee Commission dated 11/02/2022 and numbered 2022/58, the current study was approved by the Ethics Committee.

Results

In this section, the results of the analysis related to the main problem of the research are presented. Within the scope of the research, four different models were tested. In the first model, the level of mathematics belief predicting mathematical resilience was examined, while in the second model, the level of epistemological beliefs predicting mathematical resilience was examined. In the third model, the power of mathematics belief and epistemological belief values together to predict mathematical resilience; in the fourth model, the level of prediction of mathematical resilience by mathematics belief and epistemological belief sub-dimensions was examined. When the fourth model was tested, it was determined that not all the independent variables influenced the dependent variable, and the model was created with the backward selection method. The variables contributing to the model were determined as usefulness, belief that learning depends on effort and belief that learning depends on ability.

As a result of the linear regression analysis, it was determined that there was a positive moderate relationship between mathematical resilience and mathematics belief (0.554) and a positive moderate relationship between mathematical resilience and epistemological belief (0.571); when mathematics belief and epistemological belief were evaluated together, these two conceptual constructs were positively related to mathematical resilience at a moderate level (0.624). When mathematics belief and epistemological belief sub-dimensions were evaluated together, it was found that the sub-dimensions of usefulness, belief that learning depends on effort (effort) and belief that learning depends on ability (ability) had a positive, moderate (0.688) relationship with mathematical resilience (see Table 2).

Table 2. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.554[a]	.307	.304	.48711
2	.571[b]	.326	.324	.48032
3	.624[c]	.389	.384	.45837
4	.688[d]	.473	.467	.42657

a. Predictors: (Constant), Mathematics belief

b. Predictors: (Constant), Epistemological belief

c. Predictors: (Constant), Epistemological belief, Mathematics belief

d. Predictors: (Constant), Usefulness, Effort, Ability

When the table is examined, the change in mathematics belief explains 30.7% of the change in students' mathematical resilience and the change in epistemological belief explains 32.6% of the change in students' mathematical resilience. The change in mathematics belief and epistemological belief together explains 38.9% of the change in students' mathematical resilience. When usefulness, the belief that learning depends on effort, and the belief that learning depends on ability are evaluated together, the change that occurred explains 47.3% of the change in students' mathematical resilience. The regression models for these relationships are given below:

$$Mathematical\ resilience = 2.941 + 0.776 * Mathematics\ belief \quad \text{(Model 1)}$$

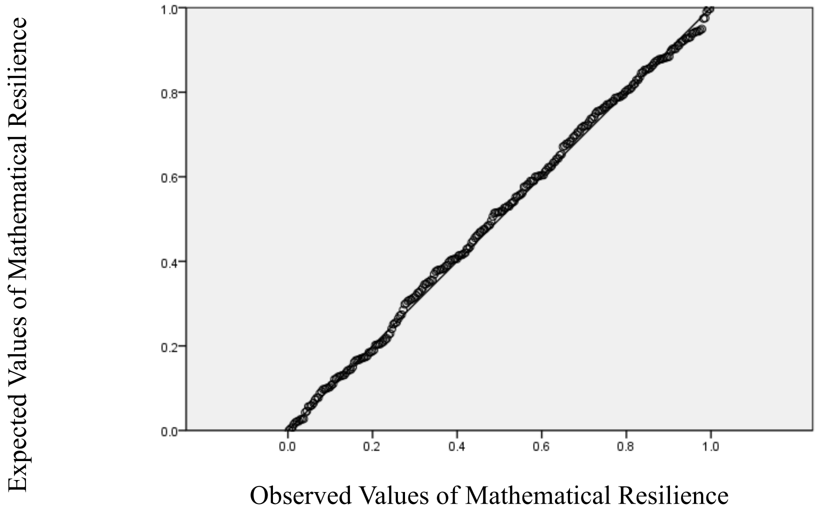
$$Mathematical\ resilience = 2.416 + 0.925 * Epistemological\ belief \quad \text{(Model 2)}$$

$$Mathematical\ resilience = 1.934 + (0.596 * Epistemological\ belief) + (0.451 * Mathematics\ belief) \quad \text{(Model 3)}$$

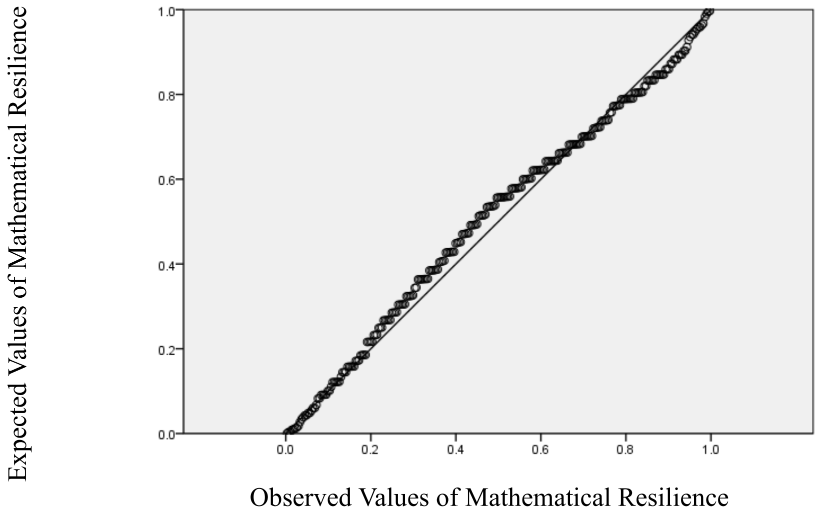
$$Mathematical\ resilience = 1.709 + (0.266 * Usefulness) + (0.590 * Effort) + (0.150 * Ability) \quad \text{(Model 4)}$$

The fits between the mathematical resilience value predicted from the above equations and the actual mathematical resilience value are shown in Figure 3, respectively.

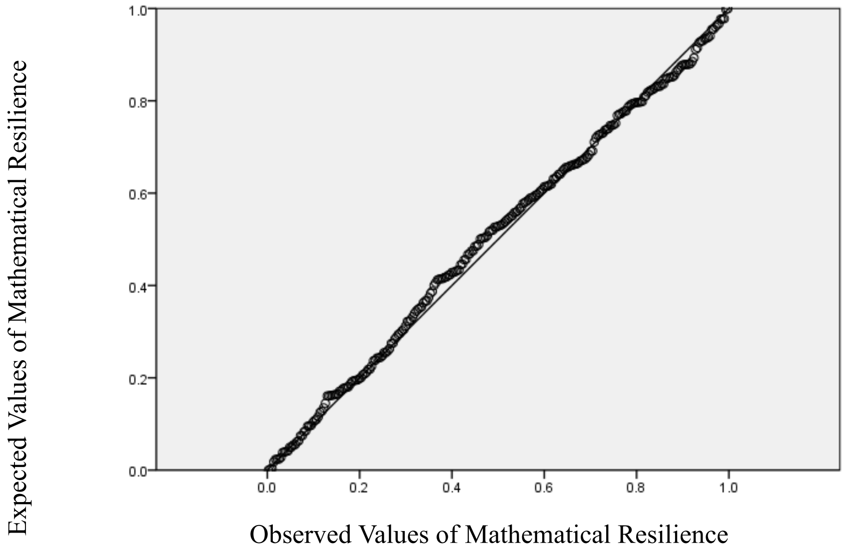
Model 1.



Model 2.



Model 3.



Model 4.

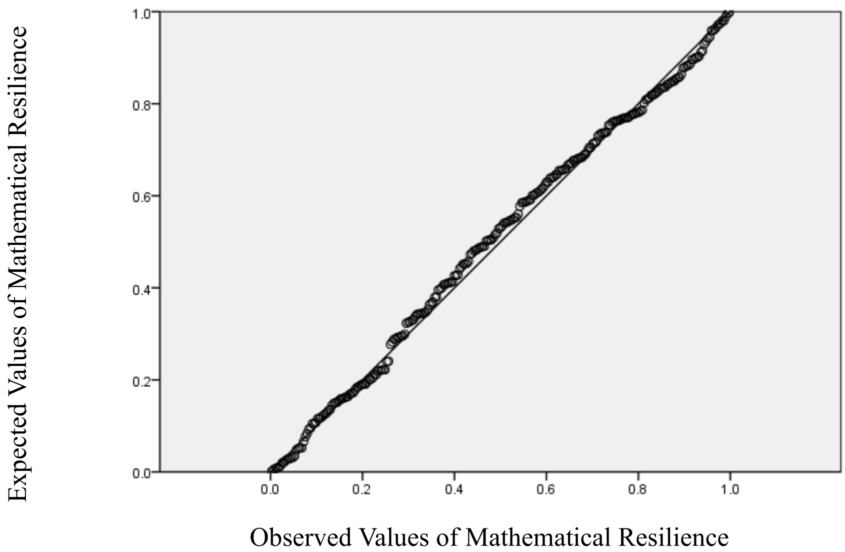


Figure 3. Relationship between Predicted and Actual Values

As can be seen from the figures, there is a good agreement between the mathematical resilience values predicted because of the equations obtained by regression analysis and the actual mathematical resilience values. That is, the prediction performance of the obtained models is high. The significance levels of the regression coefficients in the relationships in the models were analyzed with t and F tests at $\alpha=0.01$ significance level. The results of the t-test are given in Table 3.

Table 3. T-test results of the regression model[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig. (p)
		B	**Std. Error**	**Beta**		
1	(Constant)	2.941	.279		10.543	.000
	Mathematics belief	.776	.073	.554	10.672	.000
2	(Constant)	2.416	.314		7.702	.000
	Epistemological belief	.925	.083	.571	11.156	.000
3	(Constant)	1.934	.314		6.163	.000
	Epistemological belief	.596	.102	.368	5.851	.000
	Mathematics belief	.451	.088	.322	5.119	.000
4	(Constant)	1.7009	.292		5.844	.000
	Usefulness	.266	.051	.295	5.192	.000
	Effort	.590	.074	.419	8.018	.000
	Ability	.150	.039	.191	3.813	.000

a. Dependent Variable: Mathematical Resilience

As can be seen from Table 3, the significance levels obtained for the t values in the regression analysis are smaller than α=0.001 error level. Thus, it is understood that the regression coefficients in the relationships established for the prediction of mathematical resilience value are different from zero and that the relationships between the dependent variable and the independent variables exist. When the first model is examined in detail, a 1-point change in mathematics belief causes a 0.776-point change in mathematical resilience. Similarly, in the second model, a 1-point change in epistemological belief leads to a 0.925-point change in mathematical resilience. In the third model in which mathematics belief and epistemological belief were evaluated together, a 1-point change in epistemological belief affected mathematical resilience by 0.596 points, while a 1-point change in mathematics belief affected it by 0.451 points. A 1-point increase in epistemological belief and mathematics belief increases mathematical resilience by a total of 1.047 points. In the model created with the sub-dimensions, a 1-point change in the usefulness factor affects mathematical resilience by 0.266 points, a 1-point change in the effort factor affects mathematical resilience by 0.590 points and a 1-point change in the ability factor affects mathematical resilience by 0.150 points. A 1-point increase in each factor increases the individual's level of mathematical resilience by a total of 1.006 points. Regarding the significance of the established models, whether the independent variables have a linear relationship with the dependent variable was evaluated with the help of the F test. The test results are given in Table 4.

Table 4. F test results of the regression model[a]

Model		Sum of Squares	df	Mean Square	F	Sig. (p)
1	Regression	27.025	1	27.025	113.896	.000[b]
	Residual	60.980	257	.237		
	Total	88.005	258			
2	Regression	28.712	1	28.712	124.453	.000[c]
	Residual	59.292	257	.231		
	Total	88.005	258			
3	Regression	34.218	2	17.109	81.429	.000[d]
	Residual	53.787	256	.210		
	Total	88.005	258			
4	Regression	41.605	3	13.868	76.215	.000[e]
	Residual	46.400	255	.182		
	Total	88.005	258			

a. Dependent Variable: Mathematical resilience

b. Predictors: (Constant), Mathematics belief

c. Predictors: (Constant), Epistemological belief

d. Predictors: (Constant), Epistemological belief, Mathematics belief

e. Predictors: (Constant), Usefulness, Effort, Ability

According to Table 4, the results of regression analyses for mathematical resilience value were calculated as F_1= 113.896; F_2= 124.453; F_3= 81.429 and F_4= 76.215, respectively. All the significance levels calculated for these F values are less than α=0.001 error level. This shows that at least one independent variable in the models influences the dependent variable. Tolerance and VIF values were used to check whether there is a multicollinearity problem among the independent variables in the relationships between the variables established in the multiple regression model. Data on the calculated Tolerance and VIF values are given in Table 5.

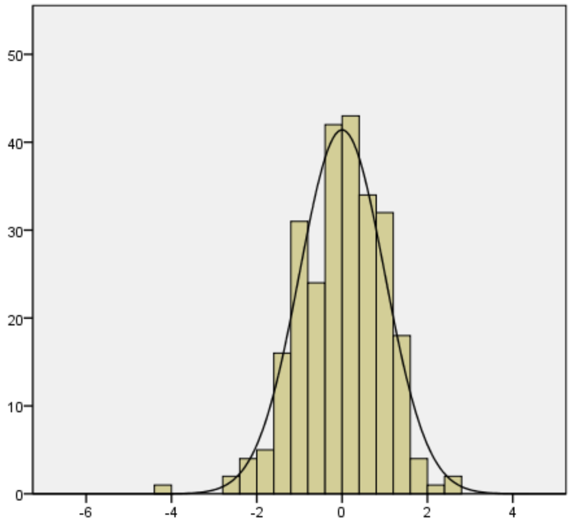
Table 5. Tolerance and VIF values for Multicollinearity Diagnosis

Model (Constant)		Tolerance	VIF
3	Epistemological belief	.603	1.659
	Mathematics belief	.603	1.659
4	Usefulness	.642	1.557
	Effort	.758	1.319
	Ability	.825	1.212

When the Tolerance and VIF values for the models were analyzed, it was observed that the Tolerance was not smaller than 0.1 for any variable and none of the VIF values was higher than 10. This shows that there is no linkage problem between the independent variables (Çokluk et al., 2016; Tabachnick & Fidel, 2013). The distribution of regression residuals for the fit of the models and that the regression assumptions are not seriously violated is given in Figure 4.

Model 1.

Dependent Variable: Mathematical Resilience

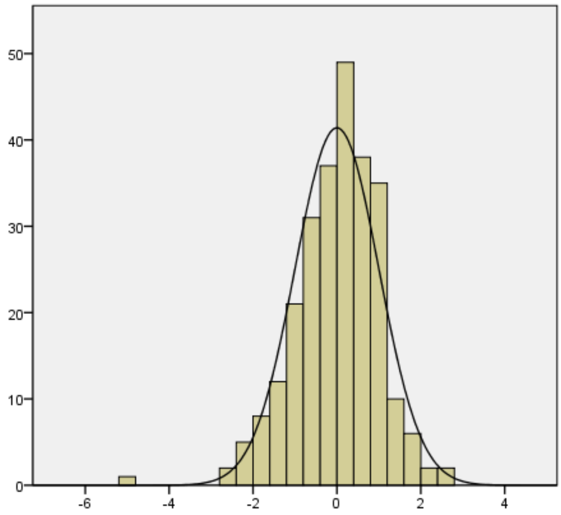


Regression Standardised Residuals

Mean= 1.32E-15
Standard Deviation= 0.998
N= 259

Model 2.

Dependent Variable: Mathematical Resilience

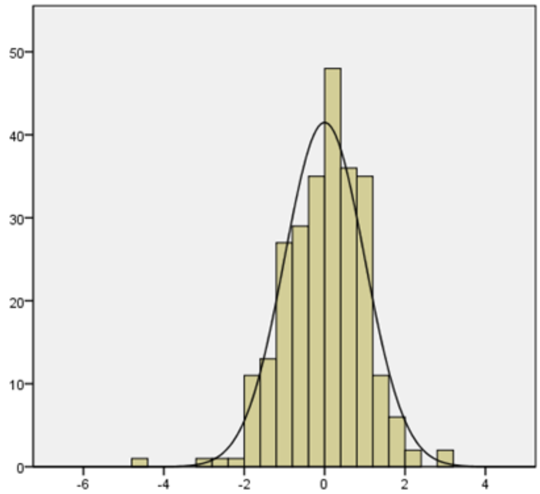


Regression Standardised Residuals

Mean= 6.79E-15
Standard Deviation= 0.998
N= 259

Dependent Variable: Mathematical Resilience

Model 3.

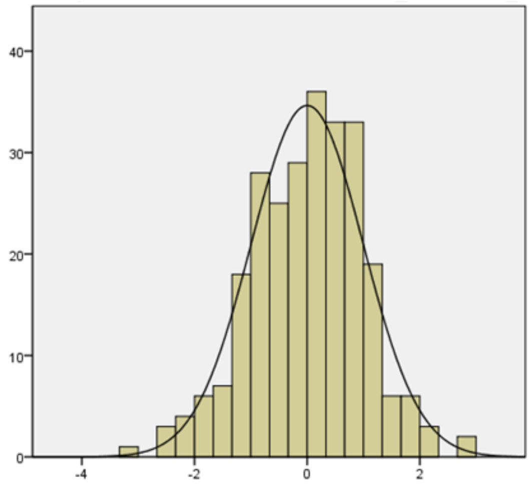


Mean= 4.06E-15
Standard Deviation= 0.996
N= 259

Regression Standardised Residuals

Dependent Variable: Mathematical Resilience

Model 4.



Mean= 1.08E-14
Standard Deviation= 0.994
N= 259

Regression Standardised Residuals

Figure 4. Regression Residuals Distribution

In a regression model, the distribution of errors (residuals) should be normally distributed with zero mean and constant variance. As seen in Figure 4, the distributions of the models are approximately bell curve shaped. In other words, the residuals in the models have a normal distribution. As a result, it can be said that the regression models obtained for the prediction of mathematical resilience are significant and valid.

Discussion and Conclusion

In the study, four models were developed to predict pre-service teachers' mathematical resilience by using mathematics belief and epistemological belief variables. Among the models developed, the model with the least accuracy is the first model. As new models were developed, the accuracy level increased. Therefore, the model with the highest accuracy was determined as the fourth model.

The individual with mathematical resilience sees mathematics as a valuable subject area. Therefore, it is important for her to do, learn, and master mathematics (Johnston-Wilder et al., 2014). The findings of the current study also confirm this. As a result of the research, it was determined that the level of beliefs that the individual has towards mathematics and doing mathematics is a statistically significant predictor for mathematical resilience. This indicates that the mathematics belief factor has a high predictive power for the level of mathematical resilience. Parallel to this result obtained from the study, Morkoyunlu and Ayhanöz (2023) also found that mathematics beliefs positively and significantly predicted mathematical resilience in middle school students.

Epistemological belief, which represents the belief in what knowledge is and how learning takes place, was also found to have a statistically significant predictive effect on mathematical resilience. This implies that the epistemological belief factor has a high predictive power for the level of mathematical resilience. The fact that epistemological belief is one of the factors predicting mathematical resilience can be explained by the fact that individuals with epistemological belief have a sense of confidence in mathematics and mathematical problems. Studies indicate that each sub-dimension of epistemological belief is related to self-confidence in mathematics (Delice et al., 2009) and belief in mathematical problem solving (Hacıömeroğlu, 2011). An individual who is confident about something does not give up and never loses hope. So, he keeps on trying until he solves the problem he faces. Continuing to strive without giving up is one of the most important aspects of mathematical resilience. Effort is the path that leads the individual to success and allows for the development of his/her talent (Beere, 2019; Baruch-Feldman, 2017). Therefore, an individual with epistemological beliefs will strive to overcome mathematical difficulties because of his/her self-confidence. This indicates that the individual has mathematical resilience. Therefore, epistemological belief appears as one of the factors predicting mathematical resilience.

As a result of the study, it was found that the predictive power of epistemological belief on mathematical resilience was higher than mathematics belief. When these two factors, which were found to have a direct effect on mathematical resilience, were evaluated together, a significant model (model 3) was obtained. The predictive power of this model for mathematical resilience was higher than the predictive power of mathematics belief (model 1) and epistemological belief (model 2) alone. Therefore, it is important to evaluate mathematics belief and epistemological belief together for mathematical resilience.

There are many dimensions to the variables of mathematics belief and epistemological belief. Some of these factors may have a high predictive power for mathematical resilience, while others may not have a significant predictive effect on mathematical resilience. For this reason, the sub-dimensions of mathematics belief and epistemological belief, which have a high power to predict mathematical resilience, were examined and it was determined which sub-dimensions had a significant effect on mathematical resilience. There are five sub-dimensions of mathematics belief. Of these, only the usefulness sub-dimension was found to have a high predictive power for mathematical resilience. Epistemological belief has three sub-dimensions. Among these, the sub-dimensions of “belief that learning depends on effort (effort)” and “belief that learning depends on ability (ability)” were found to have high predictive power for mathematical resilience. When the factors in the model are evaluated, it is seen that the factor with the highest effect on mathematical resilience is “belief that learning depends on effort”. The model created with the dimensions of usefulness, effort and ability (model 4) explains the individual's level of mathematical resilience more strongly than the other three models. Similar to this result, in the study conducted in Morkoyunlu and Ayhanöz (2023), it was determined that the usefulness and effort sub-dimensions of the mathematics belief scale (Çiftçi & Yıldız, 2020) predicted mathematical resilience.

The model with the dimensions of usefulness, effort, and ability (model 4) predicts mathematical resilience more strongly than the model with mathematics belief and epistemological belief (model 3). This is because there are some sub-dimensions within the factors that do not contribute to predicting mathematical resilience. These sub-dimensions reduce the power of the model to predict mathematical resilience. While obtaining Model 4, the model was made significant by using the backward selection method. The sub-dimensions in Model 3 that had low predictive power for mathematical resilience were removed from the model. Therefore, the predictive power of the model increased when the sub-dimensions with the least effect were removed from the model.

The effect of the belief that learning depends on effort, and ability on mathematical resilience can be explained by the growth mindset dimension of mathematical resilience. According to the growth mindset, an individual's brain capacity and math ability can be developed (Dweck, 2010). From this, it is understood that mathematics depends on ability, but that ability can be developed with effort. Individuals with this mindset see effort as important for developing ability (Murphy & Dweck, 2016). With the necessary dedication and effort, anyone can achieve success in mathematics, regardless of their brain capacity (Lee & Johnston-Wilder, 2013).

The usefulness factor, which was found to have an effect on mathematical resilience, expresses that mathematics is useful and beneficial in daily life. The effect of the usefulness factor on mathematical resilience can be explained by the value dimension of mathematical resilience. Value is the extent to which an individual finds mathematics important in achieving current or future goals (Deci et al., 1991). According to this dimension, mathematics is a part of everyone's life and is beneficial for everyone. Therefore, it makes sense that usefulness predicts mathematical resilience.

Recommendations

In the current study, the affective characteristics of mathematics belief and epistemological belief, which are thought to have an effect on mathematical resilience, were taken into consideration. This constitutes the limitation of the study. However, the lack of studies in the literature on determining the predictors of mathematical resilience makes the current study important. The present study takes an important step towards understanding the building blocks of mathematical resilience. In future studies, it may be recommended to conduct similar studies with a different sample population and a larger sample size. It is also recommended to conduct new regression studies with different affective, psychological or epistemological variables that are thought to have an effect on mathematical resilience.

As a result of the research, in order to improve students' mathematical resilience, it is recommended to support the development of mathematics beliefs, and epistemological beliefs. Specifically, instilling in students that the ability to learn can be improved, and that mathematics is a useful, and rewarding field is crucial for the development of mathematical resilience. For students to acquire these beliefs, it is recommended that both parents should conduct activities at home, and teachers should conduct activities in the classroom.

References

Alpar, R. (2011). *Çok değişkenli istatistiksel yöntemler*. Detay Yayıncılık.

Baruch-Feldman, C. (2017). *The grit guide for teens: A workbook to help you build perseverance, self-control, and a growth mindset*. New Harbinger Publications.

Beere, J. (2019). *The growth mindset edge: Your guide to developing grit*. Ulysses Press

Borboudakis, G., & Tsamardinos, I. (2019). Forward-backward selection with early dropping. *Journal of Machine Learning Research, 20*(8), 1-39.

Büyüköztürk, Ş., Kılıç-Çakmak, E., Akgün, Ö., Karadeniz, Ş., & Demirel, F. (2017). *Bilimsel araştırma yöntemleri*. Pegem Akademi

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (Sixth Edition). Routledge.

Cresswell, J. W. (2012). *Educational research* (4th ed.). Pearson.

Çiftçi, S. K., & Yıldız, P. (2020). Mathematics belief scale: Construct validity and reliability analyzes. *Mehmet Akif Ersoy University Journal of Education Faculty*, (56), 121-138. https://doi.org/10.21764/maeuefd.649705

Çokluk, Ö., Şekercioğlu G., & Büyüköztürk, Ş. (2016). *Sosyal bilimler için çok değişkenli istatistik SPSS ve Lisrel uygulamaları*. Pegem Akademi.

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *Educational Psychologist, 26*(3-4), 325-346. https://doi.org/10.1080/00461520.1991.9653137

Delice, A., Ertekin, E., Aydın, E., & Dilmaç, B. (2009). Öğretmen adaylarının matematik kaygısı ile bilgibilimsel inançları arasındaki ilişkinin incelenmesi [An investigation of the relationship between epistemological beliefs and mathematics anxiety of student teachers]. *International Journal of Human Sciences, 6*(1), 361-375.

Deryakulu, D., & Büyüköztürk, Ş. (2002). Epistemolojik inanç ölçeğinin geçerlik ve güvenirlik çalışması. *Eğitim Araştırmaları, 8*, 111–125.

Dweck, C. S. (2010). *Self-theories: Their role in motivation, personality, and development*. Psychology press.

Gürefe, N., & Akçakın, V. (2018). The Turkish adaptation of the mathematical resilience scale: Validity and reliability study. *Journal of Education and Training Studies, 6*(4), 38-47. https://doi.org/10.11114/jets.v6i3.2992

Hacıömeroğlu, G. (2011). Sınıf öğretmeni adaylarının matematiksel problem çözmeye ilişkin inançlarını yordamada epistemolojik inançlarının incelenmesi [Examining elementary preservice teachers' epistemological beliefs as predictors of beliefs about mathematical problem solving]. *Buca Faculty of Education Journal,* (30), 206-220.

Johnston-Wilder, S., & Lee, C. (2010a). Mathematical resilience. *Mathematics Teaching, 218*, 38–41.

Johnston-Wilder, S., & Lee, C. (2010b). *Developing mathematical resilience* [Paper presentation]. BERA Annual Conference 2010, University of Warwick. http://www.beraconference.co.uk/2010/

Johnston-Wilder, S., Lee, C., Garton, L., Goodlad, S., & Brindley, J. (2013). Developing coaches for mathematical resilience. In L. Gómez Chova, A. López Martínez, I. Candel Torres (Eds.), *ICERI 2013: 6th International Conference on Education, Research and Innovation* (pp. 2326-2333). IATED.

Johnston-Wilder, S., Lee, C., Garton, E., & Brindley, J. (2014). Developing coaches for mathematical resilience: Level 2. In L. Gómez Chova, A. López Martínez, I. Candel Torres (Eds.), *ICERI 2014: 7th International Conference of Education, Research and Innovation* (pp. 4457-4465). IATED.

Karasar, N. (2006). *Bilimsel araştırma yöntemi*. Nobel Yayın Dağıtım.

Kayaalp, G. T., Güney, M. Ç., & Cebeci, Z. (2015). Çoklu doğrusal regresyon modelinde değişken seçiminin zootekniye uygulanışı [Variable selection in multiple regression model application of animal science]. *Çukurova University Journal of the Faculty of Agriculture, 30*(1), 1-8.

Kooken, J., Welsh, M. E., McCoach, D. B., Johnston Wilder, S., & Lee, C. (2016). Development and validation of the mathematical resilience scale. *Measurement and Evaluation in Counseling and Development, 49* (3), 217 242. https://doi.org/10.1177/0748175615596782

Lee, C. (2006). *Language for learning mathematics- Assessment for learning in practice.* Open University Press.

Lee, C., & Johnston-Wilder, S. (2013). Learning mathematics-Letting the pupils have their say. *Educational Studies in Mathematics, 83*(2), 163-180. https://doi.org/10.1007/s10649-012-9445-3

Lee, C., & Johnston-Wilder, S. (2015). Mathematical resilience: What is it and why is it important?. S. Chinn (Ed.), *The Routledge international handbook of dyscalculia and mathematical learning difficulties* (pp. 337-345). Routledge. http://www.routledge.com/books/details/9780415822855/

Lee, C., & Johnston-Wilder, S. (2017). The construct of mathematical resilience. U. Xolocotzin Eligio (Ed.), *Understanding emotions in mathematical thinking and learning* (pp. 269-291). Elsevier Press. https://doi.org/10.1016/B978-0-12-802218-4.00010-8

Masal, E., & Takunyacı, M. (2012). The Turkish adaptation of mathematics belief scale: The validity and reliability study. *Procedia-Social and Behavioral Sciences, 64*, 123-132. https://doi.org/10.1016/j.sbspro.2012.11.015

Morkoyunlu, Z., & Ayhanöz, G. S. (2023). A relational study on the mathematical beliefs and mathematical resilience of secondary school students. *Ahi Evran University Journal of Kırşehir Education Faculty, 24*(1), 426-450. https://doi.org/10.29299/kefad.1189717

Murphy, M. C., & Dweck, C. S. (2016). Mindsets shape consumer behavior. *Journal of Consumer Psychology, 26*(1), 127-136. https://doi.org/10.1016/j.jcps.2015.06.005

Nardi, E., & Steward, S. (2003). Is mathematics T.I.R.E.D.? A profile of quiet disaffection in the secondary mathematics classroom. *British Educational Research Journal, 29*(3), 345–366. https://doi.org/10.1080/01411920301852

Pierna, J. A. F., Abbas, O., Baeten, V., & Dardenne, P. (2009). A backward variable selection method for PLS regression (BVSPLS). *Analytica Chimica Acta, 642*(1-2), 89-93. https://doi.org/10.1016/j.aca.2008.12.002

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*(3), 498–504. https://doi.org/10.1037/0022-0663.82.3.498

Schommer, M. (1993). Epistemological development and academic performance among secondary students. *Journal of Educational Psychology, 85*(3), 406–411. https://doi.org/10.1037/0022-0663.85.3.406

Steiner, L. A. (2007). *The effect of personal and epistemological beliefs on performance in a college developmental mathematics class* [Unpublished doctoral dissertation]. Kansas State University.

Tabachnick, B.G., & Fidel, L.S. (2013). *Using multivariate statistics.* Pearson.

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