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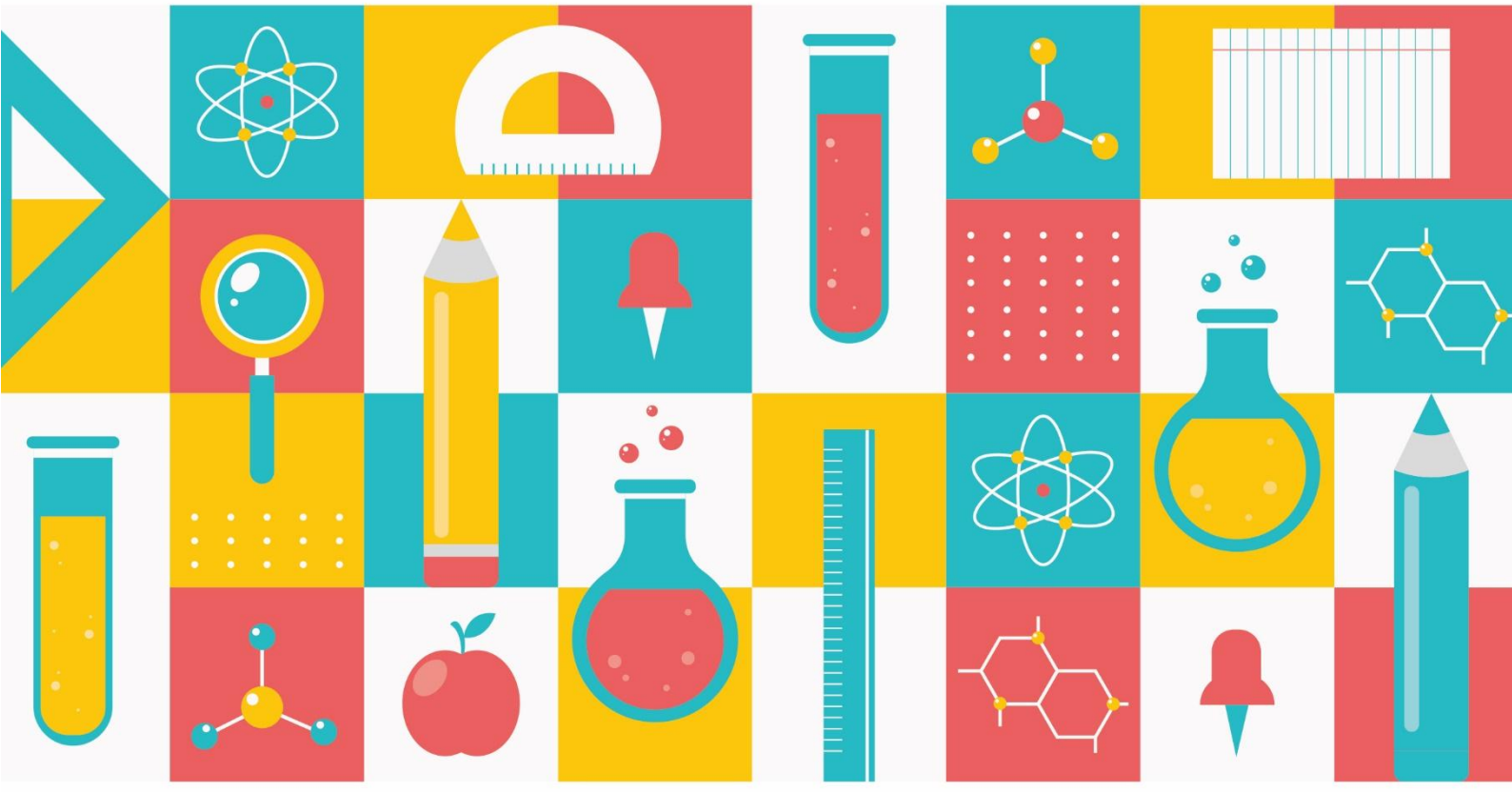

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The International Journal of Academic Studies in Science and Education (IJASSE) is a peer-reviewed scholarly online journal. The IJASSE is published quarterly in Winter and Summer. The IJASSE is published biannual as an international scholarly, peer-reviewed online journal. There is no publication fee in the IJASSE. The IJASSE is an international journal and welcomes any research papers on science and education using techniques from and applications in any technical knowledge domain: original theoretical works, literature reviews, research reports, social issues, psychological issues, curricula, learning environments, book reviews, and review articles.

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Bibliometric Analysis of Spatial Ability Studies Based on Scopus Data

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Abstract

The aim of this study was to conduct a bibliometric analysis of all studies related to spatial ability available in the Scopus database. It is expected that this research will make a significant contribution to the literature on spatial ability and serve as an important resource. In this way, researchers can gain a better understanding of the topic, evaluate the current research landscape, and use this information to plan their own studies. A bibliometric analysis method was employed in this study. Through this method, the Scopus database was searched, and 7,345 studies published from 1939 to the present were examined. We categorized the selected studies by publication year, source, authors, institutions, countries, types, subject areas, and the most highly cited works. Additionally, network maps illustrating co-authorship relationships by author and country, common keyword networks, bibliographic coupling by institution, and co-citation networks based on cited studies, journals, and authors are presented in detail in the findings section. The results indicate that numerous studies on various aspects of spatial ability have been conducted in different countries over time.

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Introduction

Mathematics education is central to the educational process because mathematics is a discipline that develops individual inquiry, analytical, and critical thinking skills. Mathematical concepts guide individuals to think logically and systematically when faced with complex situations. Additionally, by strengthening problem-solving abilities, mathematics enables individuals to develop diverse perspectives, thus contributing to more informed and effective decision-making in various areas of life (Günhan, 2006). Consequently, mathematics plays a significant role in nearly every aspect of life; therefore, mathematics education should be optimally structured and implemented (Kaçar, 2019:2).

Recent changes and developments in the field of learning have led to significant shifts in perspectives on mathematics and mathematics education. The foundation of this change is the notion that the purpose of education is not only to produce individuals who possess knowledge but also to cultivate those who have the ability to learn, conduct inquiry, ; critically, and adapt to these innovations effectively (MEB, 2018a). Learning mathematics is not limited to acquiring basic concepts and skills. It also involves understanding thought processes related to mathematics, learning strategies, and recognizing the importance of mathematics as a vital requirement in daily life (MEB, 2005). Because of its abstract nature, mathematics can pose difficulties for students in learning the subject. It has been observed that traditional teaching methods do not fully develop mathematical knowledge and skills. Therefore, it is important to revise and update these approaches according to current conditions through examination and analysis (MEB, 2018b). When necessary innovations are made, students can perceive abstract concepts in a more concrete manner and better assimilate their learning in their minds.

One of the important abstract concepts in mathematics is geometry, which also holds significant importance in our lives by contributing to our thought processes and enabling logical inferences (Birni & Karadağ, 2016). Geometry is a fundamental skill that fosters active thinking, communication, and problem-solving and interpretative abilities (Terzi, 2010). The primary aim of geometry instruction is to equip students with geometric thinking skills, thereby enhancing their creative and critical thinking skills, strengthening their ability to make predictions, and enabling them to make connections with various areas of mathematics. Furthermore, geometry education aims to develop spatial thinking skills by helping individuals understand spatial relationships, mentally manipulate objects, and solve both mathematical problems and everyday questions more effectively (MEB, 2010; Tüzün ve Cihangir, 2020).

Individuals with advanced spatial awareness can notice and examine geometric structures and patterns in their environments. They possess the ability to perceive, explain, and analyze what they see using perspectives

associated with geometry (Durmuş, 2021). Additionally, spatial ability is considered a fundamental skill for learning mathematics and geometry. Numerous studies have revealed a positive correlation between spatial and mathematical thinking abilities (e.g., Guay & McDaniel, 1977; Kösa, 2011; Tartre, 1990). Similarly, spatial ability is not only crucial for achieving success in learned subjects and is also an important and necessary skill in many areas of life. According to researchers, spatial ability plays a significant role in the development of societies with high levels of well-being and advanced living conditions, as well as in the emergence of necessary innovations (Özyaprak, 2012). Therefore, many studies have been conducted on this topic and continue to be conducted (e.g., Maeda & Yoon, 2013, 2013; Techentin et al., 2014; Xie et al., 2020).

There is substantial research indicating that spatial thinking ability can be developed through education. It has been noted that this ability can be enhanced through applications in fields such as engineering and architecture, including drawings and computer applications. Traditionally, efforts to improve spatial ability have primarily focused on university students and have been conducted through engineering and architecture programs. However, contemporary research has explored how such efforts can be adapted to lower educational levels, particularly for elementary school students. Some researchers have emphasized the importance of interacting with concrete objects to enhance spatial visualization, especially for primary and secondary school students (Werthessen 1999; Melancon 1994; Bennie and Smith 1999; Battista 1989; Gutierrez 1992; Battista and Clements, 1996; Hirstein 1981; Geddes and Fortuna 1993, cited in Olkun et al., 2014; Tosik-gün and Güyer, 2019).

Research on spatial ability has a long history (Lohman, 1979; Smith, 1964). Di and Zheng (2022) investigated the extent of technology's impact on spatial ability, and Maeda and Yoon (2013) explored the effects of spatial thinking in three-dimensional objects on gender differences. In another study, Xie et al. (2020) examined the relationship between spatial ability and mathematical ability, revealing a significant relationship between these two skills and highlighting that spatial ability positively influences logical reasoning.

Research provides valuable insights by revealing the current state of a field and identifying general trends. By reviewing the current literature and building upon previous research, these studies allow us to understand the discipline's status at a particular time. Additionally, they serve as a guide for researchers and academics regarding future research directions and trends, helping to identify gaps in the field and establish research priorities. Evaluating scientific research in a specific area plays a crucial role in shaping the field's trends and priorities by providing a foundation for future work (Falkingham & Reeves, 1997). Similarly, Dunkin (1996) emphasized the importance and necessity of synthesizing research qualities. The literature also indicates that there are studies examining various topics conducted in Turkey. When reviewing the literature on spatial ability, numerous studies have been conducted on this topic from the past to the present (Güven & Kosa, 2008;

Hendroanto et al., 2015; Lean & Clements, 1981; Olkun, 2003; Sutton & Williams, 2007; Tartre, 1990; Yıldız & Tüzün, 2011). However, a bibliometric analysis of articles published on spatial ability in Scopus has not yet been performed.

Therefore, this study aimed to conduct a bibliometric analysis of research on spatial ability based on the Scopus database. It is anticipated that this study will contribute to the literature on spatial ability and provide a comprehensive review of existing studies on the topic. This will help researchers plan their spatial abilities to observe, understand, and evaluate the current state of the field, thereby assisting them in planning their own research. The subproblems formulated within this scope are outlined below.

In the Scopus database, how is the distribution of studies on spatial ability characterized by the following categories: year, source, author, institution, country, type, subject area, and most cited works?
What does the network map look like regarding: co-authorship relationships by authors, co-authorship relationships by countries, co-occurrence of keywords, bibliography matching by institutions, co-citations of cited works, cited journals, and co-citations of cited authors?

Method

Research Design

This study aimed to conduct a bibliometric analysis of research on spatial ability based on the Scopus database. Bibliometric analysis, as used in this study, involves analyzing and examining scientific articles on various topics, their authors, and numerous other written sources (Broadus, 1987). Bibliometric analysis is an analysis technique used to evaluate the literature, which includes studies in the relevant field (books, book chapters, articles, early access publications that have not yet been published) (Mutluer, 2023).

It also provides visual maps of the interconnections between highly cited sections, the most prolific and influential authors, scientific journals, and countries related to the research topics (Kurutkan & Orhan, 2018). Through bibliometric analysis, it is possible to examine and analyze the collaborations between authors, institutions, and countries, as well as the relationships among keywords in published works on the relevant topic. Utilizing bibliometric analysis helps review the work of expert researchers in the field, evaluate their performance, and track developments in a specific topic or journal. Additionally, it supports and contributes to the development of scientifically accepted decisions in the literature. Such analyses provide valuable information about the originality and rigor of the reviewed studies (Ukşul, 2016). Based on this information, analyses using tables (by publication years, sources, authors, connections, countries, types, subject areas) and

scientific field mapping (co-authorship, co-occurrence of keywords, bibliography matching, and co-citation) have been conducted as part of the bibliometric data analysis steps.

Data Collection

In accordance with the aim of the study, research on spatial ability in the literature was examined using bibliometric analysis of studies published in the Scopus database. Scopus is described as "the largest single abstract and indexing database ever created," indexing over 14,000 titles from 4,000 publishers. The database contains 27 million abstracts extending back to 1966, including 100% coverage of MEDLINE, EMBASE, and Compendex. It encompasses literature from both English and other languages and covers Europe and the Asia-Pacific region. Scopus links cited and citing documents, indexes open-access titles, and includes over 167 million web pages and patents. It is OpenURL-compliant, performs access control for full-text access, and links to publisher sites. Scopus claims 99% citation accuracy, provides COUNTER-compliant usage reports, and offers various training options and technical support (Burnham, 2006).

In the bibliometric analysis, a literature review was conducted based on predetermined questions to identify studies that were suitable for inclusion. According to this review, studies available in Scopus were selected. During the data collection process, the content of these studies was analyzed, and experts in the field were consulted to select relevant keywords. Based on the feedback received, research was conducted using the identified keywords. The literature was examined using search terms such as "spatial thinking," "spatial ability," "spatial visualization," "spatial think* skill*," and "spatial visualization skill*," focusing on studies that included these terms in their titles, keywords, or abstracts. All studies from the past to the present, across all indices, document types, publishers, institutions, authors, languages of publication, and Scopus categories, were included in the search, resulting in the identification of 7,345 studies. These studies were exported, and the analysis phase was initiated.

Data Analysis

VOSviewer is a powerful software tool for bibliometric analysis and scientific mapping. Researchers favor this tool for visualizing and analyzing the relationships between academic publications and citations. VOSviewer is particularly useful for mapping connections between publications, coauthorship relationships, keyword clusters, and citation networks. The user-friendly interface facilitates data loading, preprocessing, and visualization with ease. The software can handle large datasets and presents results in colorful, interactive maps, enabling researchers to easily identify patterns and trends in the data. VOSviewer is an important tool for assessing scientific impact and understanding the dynamics of research fields (Arruda et al., 2022).

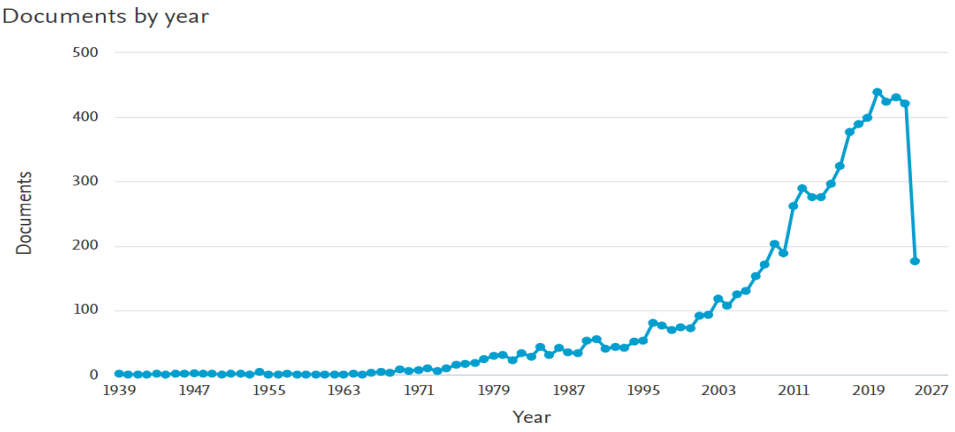
In this study, the Scopus database was used, and maps were created and analyzed using the bibliometric mapping feature of VOSviewer for the analyses. Findings related to predetermined questions for selected studies in Scopus were directly tabulated from the database. Thus, both tabular analyses from Scopus and bibliometric analyses were conducted using VOSviewer and interpreted. The obtained results are detailed in the finding section.

Validity and Reliability of the Study

In this bibliometric analysis research, the literature review, identification, and selection of relevant studies, formulation of core problems related to the topic, examination of selected studies under consistent headings, synthesis, and reporting are presented in detail. The objectives of this research and the problems defined for this study are clearly and explicitly presented. Ensuring the validity of the examined and synthesized studies is crucial for reliability. Therefore, to minimize errors, the selected studies were exported and thoroughly reviewed over an extended period. Consultations were conducted with experts in the field, and a consensus was reached before analyzing the obtained information.

Findings

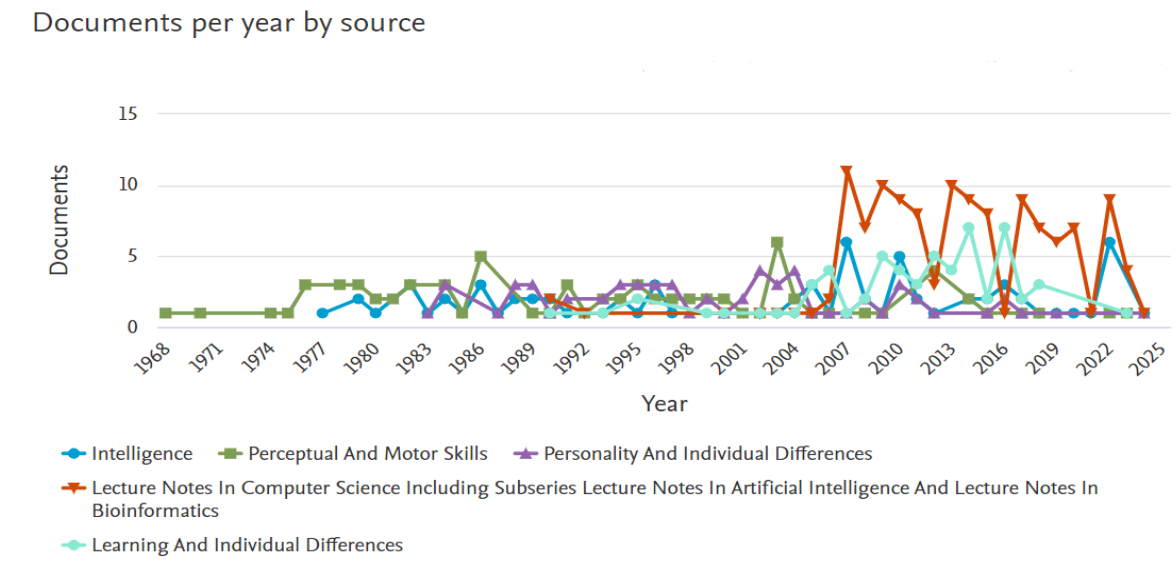
In line with the research topic, the distribution of studies in the Scopus database was examined based on publication years, sources, authors, citations, countries, types, and subject areas. Subsequently, network analyses were conducted to examine co-authorship (authors, countries), co-occurring keywords, bibliographic coupling (authors, journals, countries), and co-citation (authors, papers, journals). The distribution of published studies on spatial ability by years is provided below.



Graph 1. Distribution of Articles by Year

As shown in Graph 1, research on spatial ability began in 1939, with a general increase in the number of studies over the years, except for recent years. It is noted that no studies (N=0) on spatial ability were conducted in certain years (1940, 1941, 1942, 1944, 1950, 1953, 1955, 1956, 1958, 1959, 1960, 1961, 1962, 1963, 1965). The highest number of studies was conducted in 2020 (N=439). Since 1974, there has been a noticeable increase in interest in the region. Despite fluctuations between years, an overall upward trend was observed. Although a decline was observed in 2024, it should be noted that the number of studies represented in the graph only covers the first five months of the year.

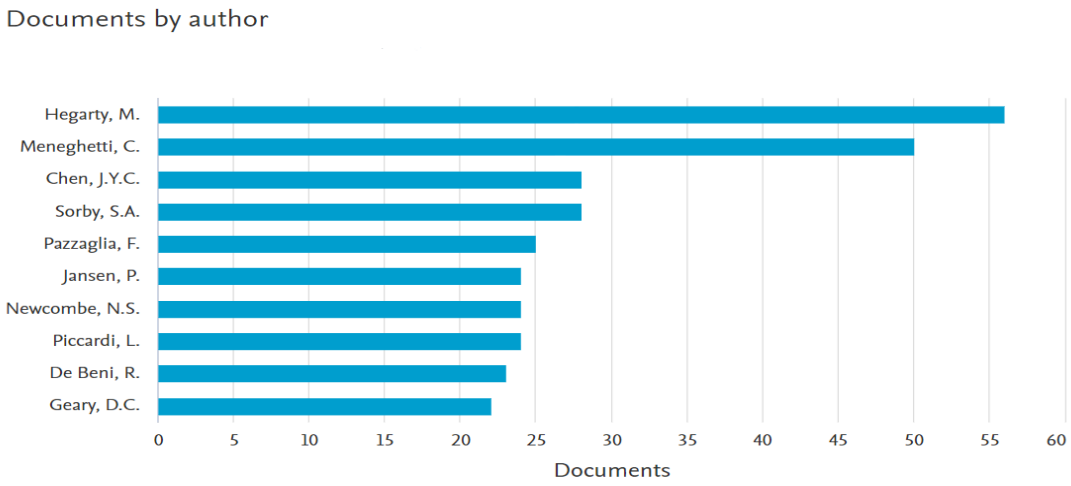
The annual distribution of spatial ability studies based on the top five sources of publication is presented below.



Graph 2. Annual Distribution of Articles by the Top 5 Sources

Graph 2 shows the distribution of studies on spatial ability across sources, with the top-ranked source being the journal Lecture Notes in Computer Science, including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics (N=130). This is followed by Intelligence (N=77), Perceptual and Motor Skills (N=77), Personality and Individual Differences (N=63), and Learning and Individual Differences (N=62). The journal Lecture Notes in Computer Science, including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, has published relevant studies since 1990. Intelligence has been published from 1978 to the present, Perceptual and Motor Skills from 1968 to 2023, Personality and Individual Differences from 1984 to the present, and Learning and Individual Differences from 1990 to 2023.

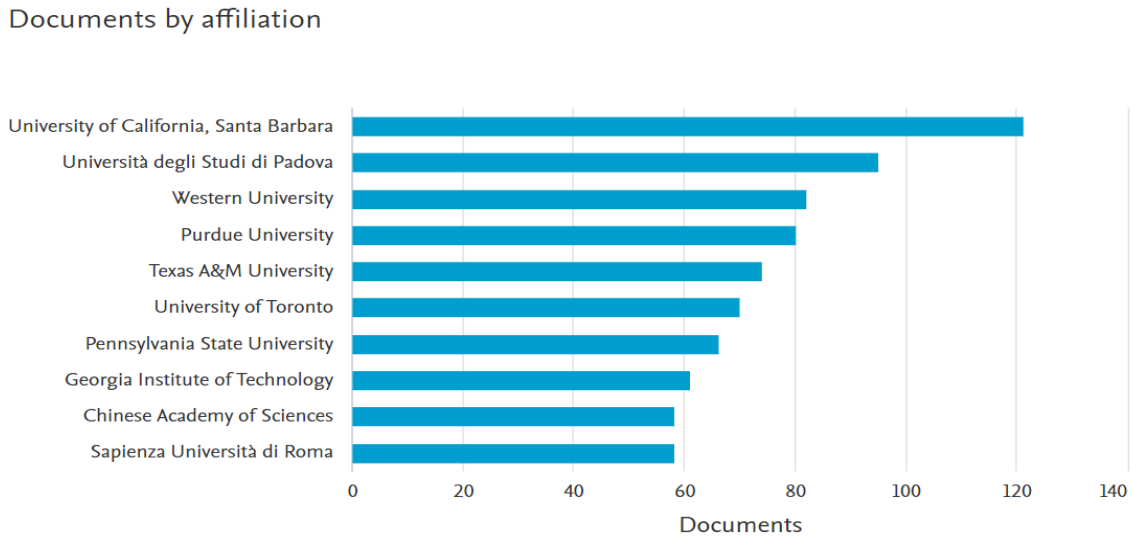
The distribution of studies on spatial ability by the top 10 authors and most published papers is presented below.



Graph 3. Distribution of the Top 10 Authors with the Most Publications

Graph 3 shows that the author of the most studies on spatial ability is M. Hegarty (N=56). C. Meneghetti (N=50), J.Y.C. Chen (N=28), S.A. Sorby (N=28), F. Pazzaglia (N=25), P. Jansen (N=24), N.S. Newcombe (N=24), L. Piccardi (N=24), R. De Beni (N=23), and D.C. Geary (N=22) follow.

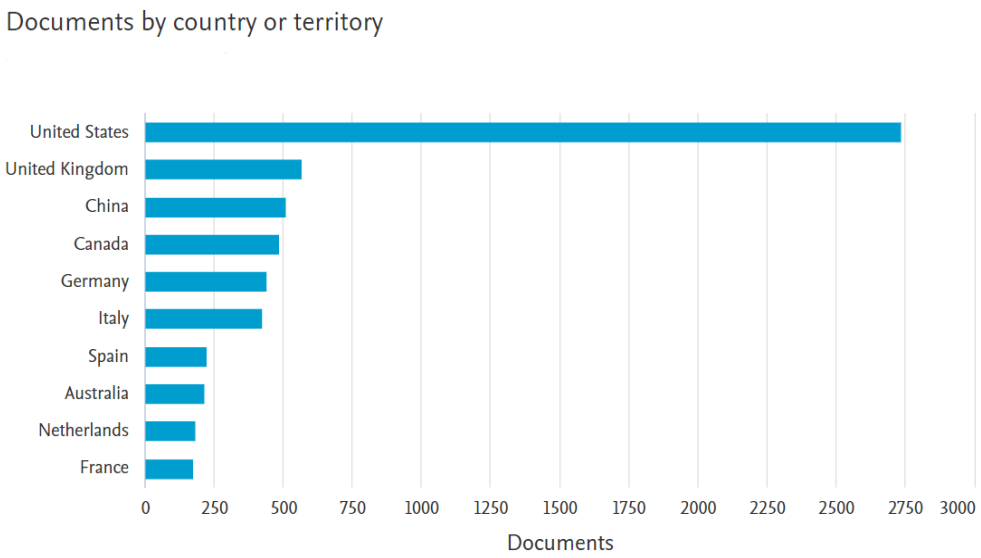
The distribution of spatial ability studies by the top 10 institutions is provided below.



Graph 4. Distribution of Studies by Top 10 Institutions

Graph 4 shows that the institution with the highest number of studies on spatial ability is the University of California (N=121). This was followed by Università degli Studi di Padova (N=95), Western University (N=82), Purdue University (N=80), Texas A&M University (N=74), University of Toronto (N=70), Pennsylvania State University (N=66), Georgia Institute of Technology (N=61), Chinese Academy of Sciences (N=58), and Sapienza Università di Roma (N=58).

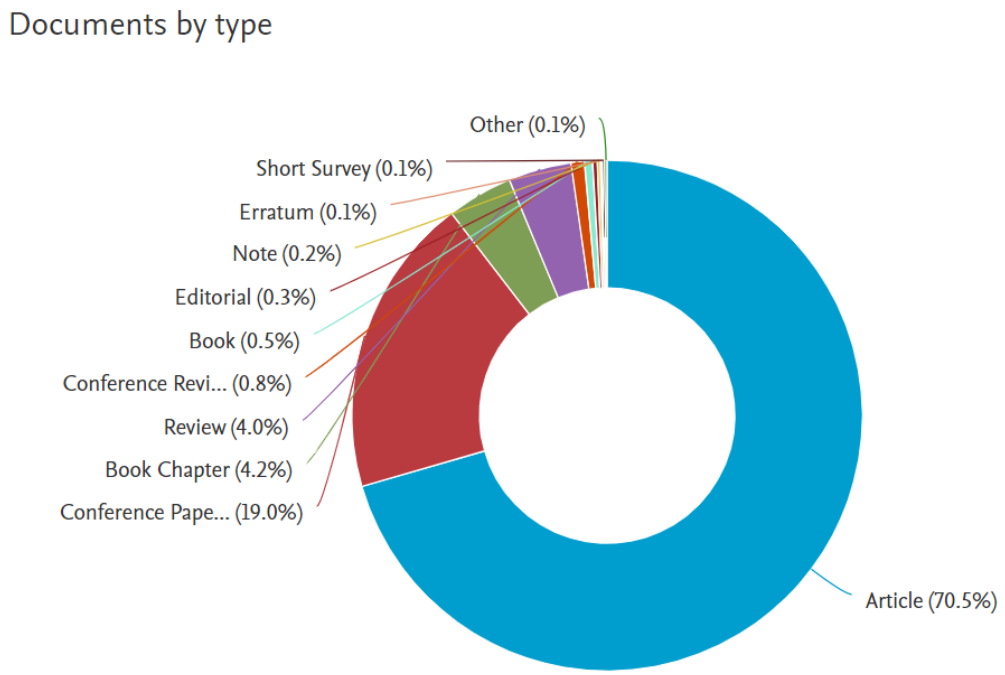
The distribution of studies on spatial ability by the top 10 countries is provided below.



Graph 5. Distribution of Studies by Top 10 Countries

Graph 5 shows that the country with the highest number of studies on spatial ability is the United States (N=2,732). This is followed by the United Kingdom (N=566), China (N=506), Canada (N=483), Germany (N=437), Italy (N=423), Spain (N=221), Australia (N=211), the Netherlands (N=180), and France (N=172).

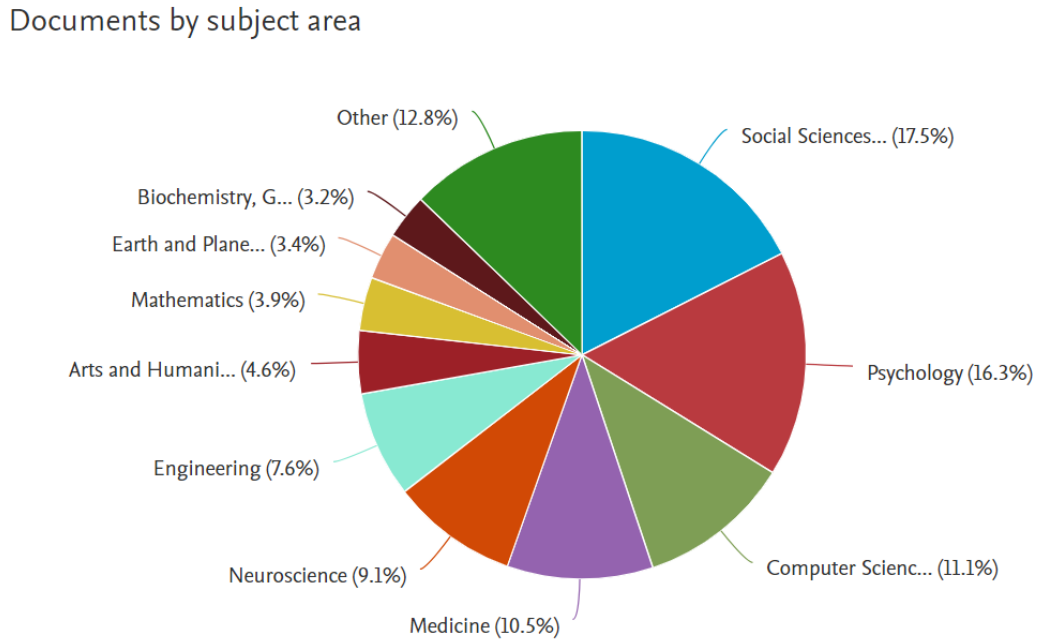
The distribution of studies on spatial ability by type is presented below.



Graph 6. Distribution of Studies by Type

Graph 6 shows that the most common type of publication on spatial ability is a journal article (N=5,181). This is followed by conference proceedings (N=1,398), book chapters (N=306), reviews (N=293), conference reviews (N=62), books (N=38), editorials (N=22), notes (N=14), corrections (N=10), and other types (N=21).

The distribution of studies on spatial ability by subject area is provided below.



Graph 7. Distribution of Studies by Subject Area

Graph 7 shows that the leading subject area for studies on spatial ability is Social Sciences (N=2,319). This is followed by Psychology (N=2,152), Computer Science (N=1,467), Medicine (N=1,391), Neuroscience (N=1,209), Engineering (N=1,011), Arts and Humanities (N=602), Mathematics (N=510), Earth and Planetary Sciences (N=446), Biochemistry, Genetics and Molecular Biology (N=428), and other categories (N=1,690).

The distribution of the top five most-cited studies on spatial ability published in the Scopus database is presented below.

Table 1. Distribution of the Top Five Most-Cited Works in the Scopus Database

	Belge başlığı	Yazarlar	Kaynak	Yıl	Alıntılar
1	Article **Neurocognitive deficit in schizophrenia: A quantitative review of the evidence** Show abstract Full Text View at Publisher Related documents	Heinrichs, R.W., Zakzanis, K.K.	Neuropsychology, 12(3), pp. 426–445	1998	2,375
2	Article **Emergence and characterization of sex differences in spatial ability: a meta-analysis.** Show abstract Full Text View at Publisher	Linn, M.C., Petersen, A.C.	Child development, 56(6), pp. 1479–1498	1985	2,243
3	Article **Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables** Show abstract Full Text View at Publisher Related documents	Voyer, D., Voyer, S., Bryden, M.P.	Psychological Bulletin, 117(2), pp. 250–270	1995	2,096
4	Article **Mental rotations, a group test of three-dimensional spatial visualization** Full Text View at Publisher	Vandenberg, S.G., Kuse, A.R.	Perceptual and Motor Skills , 47(2), pp. 599–604	1978	1,927
5	Article **Mapping ecosystem service supply, demand and budgets** Show abstract Full Text View at Publisher Related documents	Burkhard, B., Kroll, F., Nedkov, S., Müller, F.	Ecological Indicators, 21, pp. 17–29	2012	1,602

Table 1 shows the type, authors, publication years, and citation counts of the top five most-cited studies on spatial ability. All five highly cited studies were journal articles. The most cited paper is "Neurocognitive Deficit in Schizophrenia: A Quantitative Review of the Evidence" (Heinrichs, R.W., & Zakzanis, K.K.), which was published in Neuropsychology in 1998 and has received 2,375 citations since its publication. This is followed by "Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis" (Linn, M.C., & Petersen, A.C.), published in Child Development in 1985, with 2,443 citations; "Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis and Consideration of Critical Variables" (Voyer, D., Voyer, S., & Bryden, M.P.), published in Psychological Bulletin in 1995, with 2,096 citations; "Mental Rotations, A Group Test of Three-Dimensional Spatial Visualization" (Vandenberg, S.G., & Kuse, A.R.), published in Perceptual and Motor Skills in 1978, with 1,927 citations; and "Mapping Ecosystem Service Supply, Demand, and Budgets" (Burkhard, B., Kroll, F., Nedkov, S., & Müller, F.), published in Ecological Indicators in 2012, with 1,602 citations.

A network map showing co-authorship relationships among authors of studies on spatial ability is provided below.

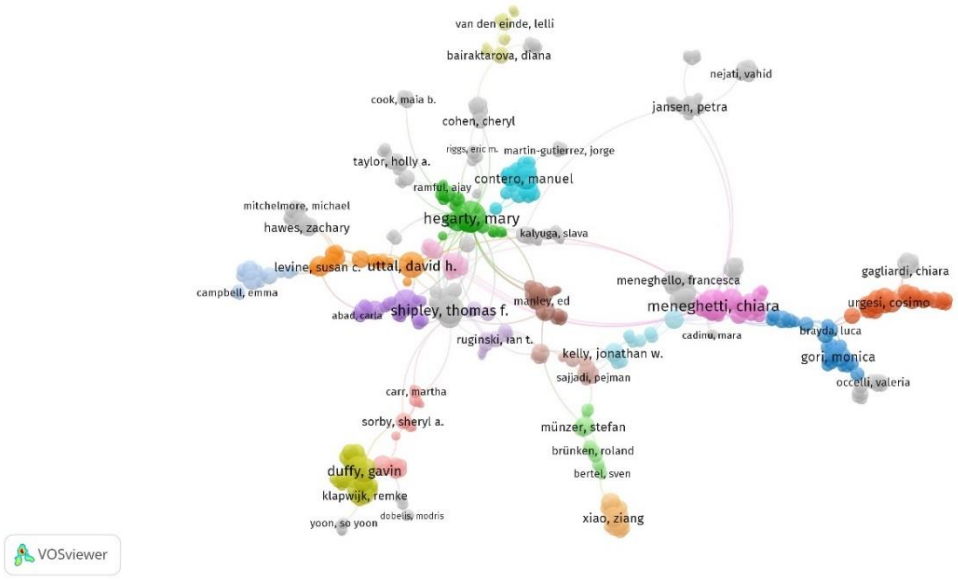


Figure 1. Coauthorship Network Map of Authors in the Studies

Figure 1 shows the co-authorship network map of the authors of the spatial ability. To identify co-authorship relationships, a minimum of two publications and two citations per author were established. Based on these criteria, the total number of authors listed in the included studies was 2,029, with 448 forming a large cluster. The analysis revealed that the largest connected group consisted of 38 clusters (number of connections: 1,086, total connection strength: 2,035). Each of these 38 clusters contains between 2 and 9 co-authors. Among these authors, Mary Hegarty (number of connections: 34, total connection strength: 69), Chiara Meneghetti (number of connections: 32, total connection strength: 124), and F. Thomas Shipley (number of connections: 26, total connection strength: 51) was a particularly prominent. A common link among these researchers is their focus on understanding how people process, represent, and utilize spatial information and tasks.

A network map showing coauthorship relationships by country for spatial ability studies is provided below.

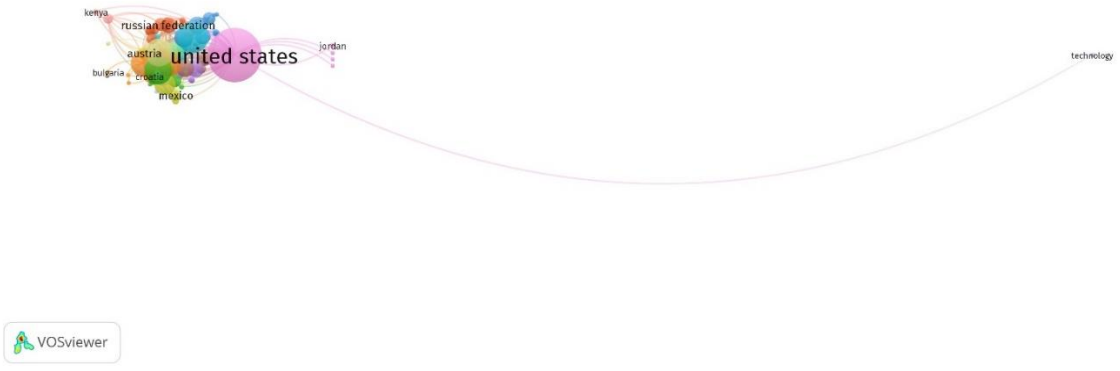


Figure 2. Co-Authorship Network Map by Country in the Studies

Figure 2 shows the coauthorship network map by country for studies on spatial ability. To identify co-authorship relationships, a minimum of two publications and two citations per author were established. Based on these criteria, the total number of countries listed in the studies was 91, with 88 countries constituting a large cluster. The analysis revealed that the largest connected group consists of 9 clusters (number of connections: 520, total connection strength: 1,639). Each of these 9 clusters contains between 2 and 9 co-authoring countries. Among these countries, the United States (number of connections: 60, total connection strength: 557), the United Kingdom (number of connections: 52, total connection strength: 309), Germany (number of connections: 47, total connection strength: 215), Canada (number of connections: 39, total connection strength: 186), Australia (number of connections: 33, total connection strength: 132), Switzerland (number of connections: 31, total connection strength: 104), the Netherlands (number of connections: 30, total connection strength: 95), France (number of connections: 29, total connection strength: 105), Italy (number of connections: 28, total connection strength: 125), and Turkey (number of connections: 26, total connection strength: 52) are particularly prominent.

A network map showing the co-occurrence of key terms in spatial ability studies is provided below.

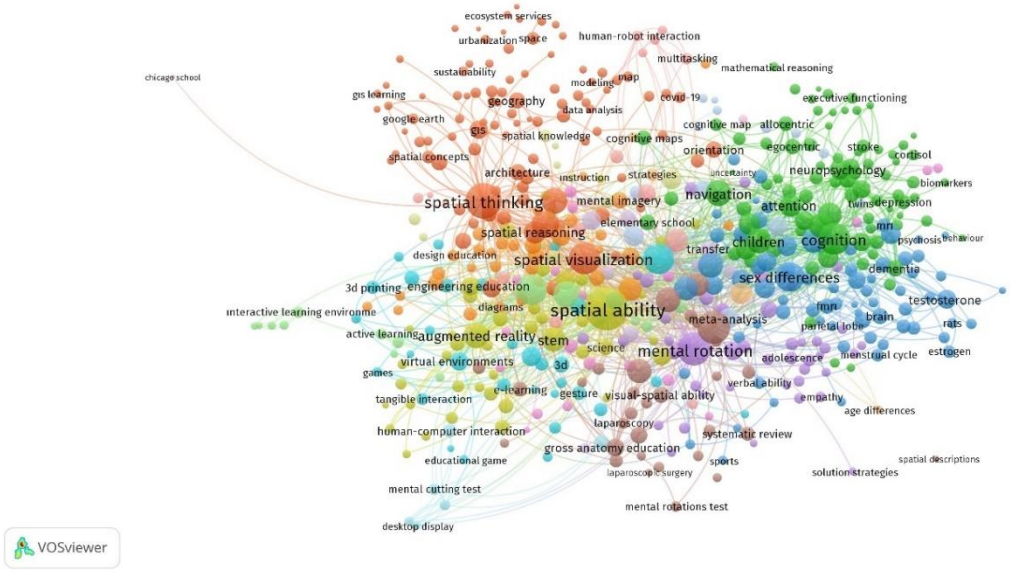


Figure 3. Co-Occurrence Network Map of Keywords in the Studies

Figure 3 shows that common key terms in spatial ability studies had a minimum co-occurrence of five. The total number of key terms was 532. The analysis revealed that the largest connected group of common key terms comprised 18 clusters (number of connections: 5,889, total connection strength: 9,915). Each of these 18 clusters contains between 5 and 44 common key terms. Among these common key terms, "spatial ability" (number of connections: 338, total connection strength: 1,435) had the highest connection strength. This was followed by "spatial thinking" (number of connections: 209, total connection strength: 506), "mental rotation"

(number of connections: 174, total connection strength: 582), "spatial visualization" (number of connections: 154, total connection strength: 350), and "cognition" (number of connections: 153, total connection strength: 363) as frequently used common key terms.

A network map showing citation matching by institutions for spatial ability studies is provided below.

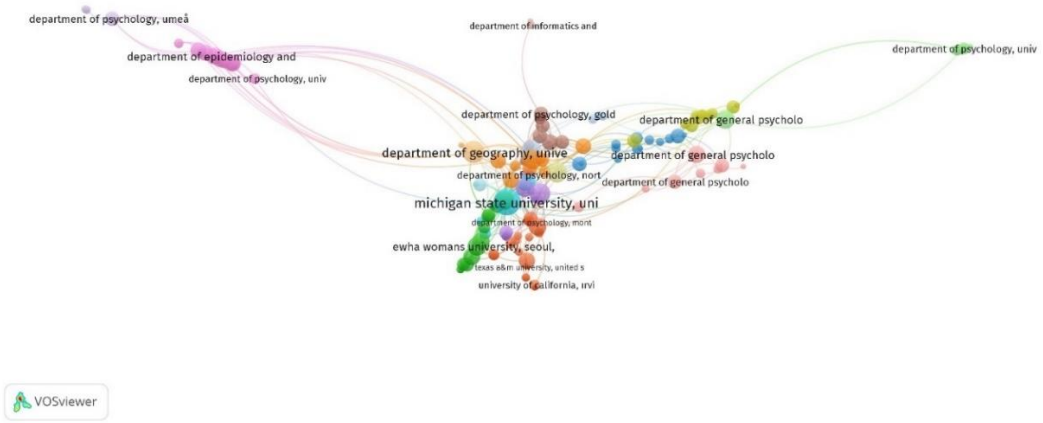


Figure 4. Bibliographic Coupling Network Map of Institutions in the Studies

Figure 4 shows that in the citation matching by institutions for studies on spatial ability, the criteria were a minimum of three publications and three citations per institution. According to these criteria, 146 out of 210 institutions met the requirements. These 146 institutions were organized into 17 clusters (number of connections: 383, total connection strength: 639). Each cluster contains between 2 and 20 institutions. Among these institutions, Michigan State University (number of connections: 33, total connection strength: 47), the University of California Santa Barbara (number of connections: 20, total connection strength: 29), Temple University (number of connections: 18, total connection strength: 23), and the University of Padua (number of connections: 14, total connection strength: 33) were particularly prominent. A network map showing the co-citation relationships of cited works in spatial ability studies is provided below.

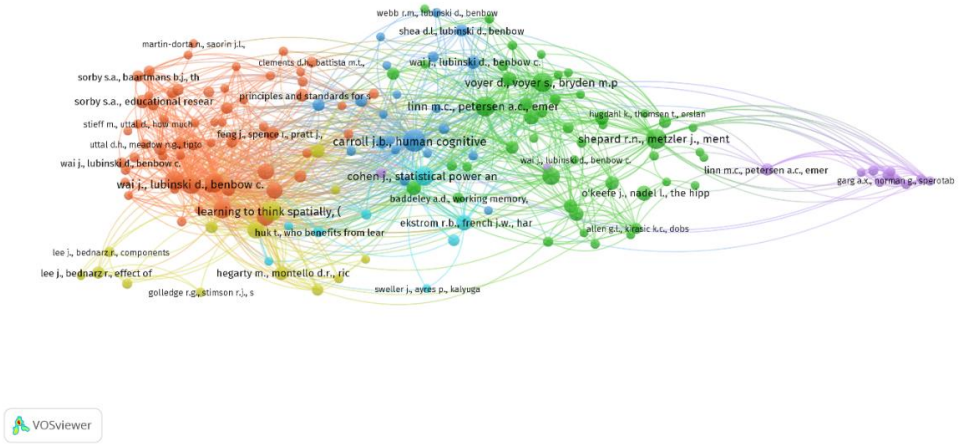


Figure 5. Co-Citation Network Map of Cited Works in Different Studies

Figure 5 shows that for spatial ability studies, the co-citation analysis of cited works was conducted with a minimum co-citation count of 20. According to this criterion, there are 199,915 cited works, of which 162 meet this criterion. The network map resulting from the analysis consists of a total of 6 clusters (number of connections: 5,212, total connection strength: 14,598), with each cluster containing between 8 and 60 cited works. The most frequently cited works in these studies are, in order: Carroll J.B., Human Cognitive Abilities: A Survey of Factor Analytic Studies (1993) (number of connections: 147, total connection strength: 907), Cohen J., Statistical Power Analysis for the Behavioral Sciences (1988) (number of connections: 130, total connection strength: 423), and Linn M.C. & Petersen, A. C. (1985). Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis (1985) (number of connections: 125, total connection strength: 703).

A network map showing the co-citation relationships of cited journals in spatial ability studies is provided below.

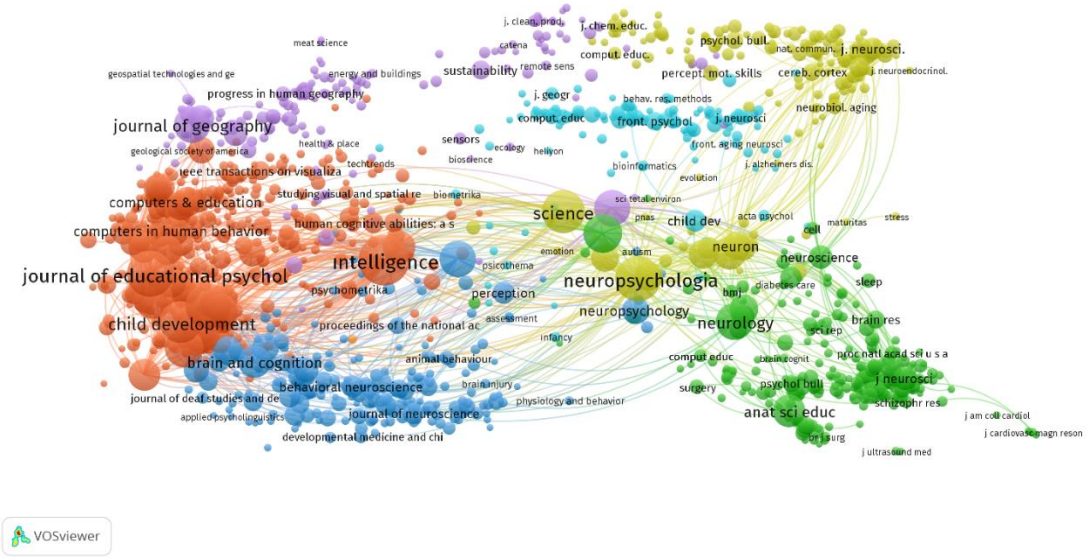


Figure 6. Co-Citation Network Map of Cited Studies

Figure 6 shows that for spatial ability studies, the co-citation analysis of cited journals was conducted with a minimum co-citation count of 20. Accordingly, 67,295 journals were cited, of which 1,330 met the criteria. The network map resulting from the analysis consists of a total of 7 clusters (number of connections: 182,047, total connection strength: 2,269,534), with each cluster containing between 1 and 403 cited journals. Among these journals, the most prominent ones are Science (number of connections: 1,288, total connection strength: 59,423), Plos One (number of connections: 1,234, total connection strength: 43,069), Nature (number of connections: 1,203, total connection strength: 40,716), Intelligence (number of connections: 1,181, total

connection strength: 83,432), Neuropsychologia (number of connections: 1,164, total connection strength: 78,585), and Cognition (number of connections: 1,116, total connection strength: 44,030).

A network map showing the co-citation relationships of cited authors in spatial ability studies is provided below.

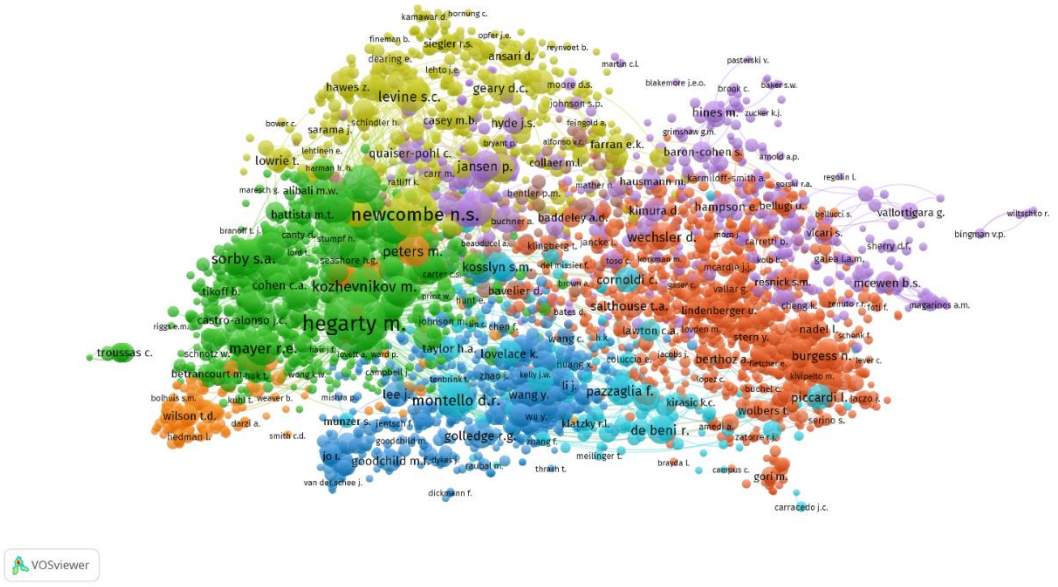


Figure 7. Co-Citation Network Map of Cited Authors in a Cross-sectional Study

Figure 7 illustrates that the minimum threshold for co-citations among cited authors in spatial ability research is set at 20. Accordingly, 238,481 authors were cited, with 3,968 meeting the established criteria. The network map comprises a total of 8 clusters (with a connection count of 1,782,387 and a total connection strength of 10,010,890), with each cluster containing between 130 and 1,172 cited authors. Among these authors, the most prominent are M. Hegarty (with 3,697 connections and a total connection strength of 287,348), N.S. Newcombe (with 3,576 connections and a total connection strength of 195,862), M.C. Linn (with 3,492 connections and a total connection strength of 70,524), D. Voyer (with 3,458 connections and a total connection strength of 87,831), D.L. Uttar (with 3,327 connections and a total connection strength of 93,852), D. Lubinski (with 3,257 connections and a total connection strength of 104,342), and J. Wai (with 3,169 connections and a total connection strength of 51,386).

Discussion and Conclusion

Spatial ability encompasses the skill of designing new scenarios by mentally rotating, unfolding, or folding objects (Kuşçu Kılınç, 2022). These skills are crucial in many professions, necessitating individuals to possess

these skills (Turgut & Yenilmez, 2012). Therefore, students must develop and strengthen these critical abilities at a young age. Numerous studies in this field have focused on understanding and enhancing spatial abilities.

Spatial ability has gained significance as a scientific discipline (Lohman, 1993, cited in Ercan, 2018). In this context, a bibliometric analysis of articles related to spatial ability in the Scopus database was conducted. The bibliometric data analysis of studies related to spatial ability in Scopus, spanning from 1939 to the present, is expected to contribute to the field and assist experts in identifying gaps in the literature for future research planning.

In this study, searches were conducted using the keywords "spatial thinking," "spatial visualization," "spatial ability," "spatial thinking skill," and "spatial visualization skill" and their English equivalents: "spatial thinking, spatial ability, spatial visualization, spatial think* skill*, spatial visualization skill*". Studies containing these terms in the title, keywords, or abstract were identified and examined. The search included all past and present studies across all indices, document types, publishers, institutions, authors, languages, and Scopus categories, resulting in a total of 7,345 works.

Analysis of the number of studies by year indicates a noticeable increase in interest in research on this topic since 1974. This increase can be attributed to several factors, including shifts in focus and new reforms in education after the 1970s (Gagne, R. M. (1985) cited in Dokumaci Sütçü, 2020), and advancements in computer technology (Kirsch I. S. (1980) Babu & Ganesan, 2019; Johnson R.B. (1990) cited in Piburn et al., 2005). Although fluctuations have occurred over the years, a general upward trend has been observed. Despite the decline noted in 2024, it should be noted that the research count represented in the graph pertains to the first five months of the year.

When examining the distribution of published works on spatial ability by source, the first position is held by Lecture Notes in Computer Science, including Subseries Lecture Notes in Artificial Intelligence, and Lecture Notes in Bioinformatics. Intelligence, Perceptual and Motor Skills, Personality and Individual Differences, and Learning and Individual Differences follow. The journal Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics has published relevant studies from 1990 to the present. Intelligence has been published since 1978, Perceptual and Motor Skills from 1968 to 2023, Personality and Individual Differences from 1984, and Learning and Individual Differences from 1990 to 2023. A review of these journals reveals that each addresses a different aspect of spatial ability. For example, intelligence serves as a platform for publishing research related to spatial ability because it is a significant component in intelligence measurement and publishes new findings and theories in this area. Perceptual and motor skills deal with both spatial ability and motor skills, with some studies focusing on the

intersection of these areas, as spatial ability involves understanding and processing environmental information, whereas motor skills pertain to physical interaction with the environment. Personality and Individual Differences examines the effects of spatial ability on individual differences. This study explores how spatial ability is related to personality traits and individual variations. Finally, Learning and Individual Differences investigates the relationship between spatial ability, learning processes, and individual differences. This journal focuses on how spatial ability influences learning strategies and success.

Among the researchers with the greatest contributions to the field of spatial ability in the Scopus database from the past to the present, M. Hegarty is the most prolific author. Hegarty is a distinguished researcher who has made significant contributions to spatial ability research. Notably, Hegarty employed various experimental approaches to understand how individuals process and represent spatial information, with a particular focus on cognitive processes involved in spatial visualization. His research has addressed topics such as the role of spatial ability in education, learning strategies, and cognitive mapping. For example, in one of his studies, he investigated individuals' abilities to mentally rotate images of three-dimensional objects, exploring the development and impact of spatial transformation skills (Cognitive Processes in Comprehension of Spatial Language). Hegarty's research has deepened our understanding of how spatial ability can be measured and developed.

The institution with the highest volume of spatial ability research is the University of California. It is followed by Università degli Studi di Padova, Western University, Purdue University, Texas A&M University, the University of Toronto, Pennsylvania State University, the Georgia Institute of Technology, the Chinese Academy of Sciences, and Sapienza Università di Roma. Similarly, the country with the greatest research on spatial ability is the United States. This is followed in order by the United Kingdom, China, Canada, Germany, Italy, Spain, Australia, the Netherlands, and France. This distribution indicates that research on spatial ability is being conducted and continues to be pursued at various locations and institutions around the world.

The majority of publications in the field of spatial ability are in the form of journal articles. This trend may be attributed to the fact that research in this area often involves experimental studies, theoretical analyses, and literature reviews. Spatial ability plays a significant role in cognitive psychology, educational sciences, and applied fields; thus, this variety allows for the exploration of different aspects of spatial ability.

The top research field on spatial ability is the social sciences. Psychology, Computer Science, Medicine, Neuroscience, Engineering, Arts and Humanities, and Mathematics follow. The prominence of the social sciences as the leading field may be attributed to its broad perspective, which encompasses a wide range of interdisciplinary approaches to spatial ability.

An analysis of the top five most-cited works on spatial ability in the Scopus database reveals that all are journal articles. The most-cited article among these top five is "Neurocognitive Deficit in Schizophrenia: A Quantitative Review of the Evidence," published in Neuropsychology in 1998 by Heinrichs et al., and has received 2,375 citations since its publication. This is followed by "Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis," published in Child Development in 1985 by Linn, M.C., and Petersen, A.C., with 2,443 citations; "Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis and Consideration of Critical Variables," published in Psychological Bulletin in 1995 by Voyer, D., Voyer, S., and Bryden, M.P., with 2,096 citations; "Mental Rotations, a Group Test of Three-Dimensional Spatial Visualization," published in Perceptual and Motor Skills in 1978 by Vandenberg, S.G., and Kuse, A.R., with 1,927 citations; and "Mapping Ecosystem Service Supply, Demand and Budgets," published in Ecological Indicators in 2012 by Burkhard, B., Kroll, F., Nedkov, S., and Müller, F., with 1,602 citations.

An examination of the co-authorship network map for research on spatial ability revealed that 2,029 authors, including M. Hegarty emerged as the most prominent figure among them. M. Hegarty's work and contributions to the field of spatial ability stand out significantly and provide substantial contributions to the literature.

An analysis of the coauthorship network map by country for research on spatial ability lists 91 countries. Among these, the United States is the most prominent. The following countries are in order: the United Kingdom, Germany, Canada, Australia, Switzerland, the Netherlands, France, Italy, and Turkey. This ranking indicates that research on spatial ability is being conducted worldwide.

An analysis of the co-occurrence network map of keywords in research on spatial ability revealed that the term "spatial ability" is the most frequently used. Other commonly used keywords include "spatial thinking," "mental rotation," "spatial visualization," and "cognition." The prominence of these keywords indicates that spatial ability can be divided into multiple subfields, and research is being conducted across these areas.
An analysis of the citation network map by institution for research on spatial ability identified Michigan State University, University of California Santa Barbara, Temple University, and University of Padua as prominent institutions. Similarly, when researchers examine the data by country, the United States stands out. This indicates that significant research on spatial ability is also being conducted at these universities.

An analysis of the co-citation network map for research on spatial ability reveals that the most frequently cited works are "Human Cognitive Abilities: A Survey of Factor Analytic Studies" (1993) by J.B. Carroll, "Statistical Power Analysis for the Behavioral Sciences" (1988) by J. Cohen, and "Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis" (1985) by M.C. Linn and A. C. Petersen. These three studies have been extensively cited. Carroll's work, "Human Cognitive Abilities: A Survey of Factor Analytic Studies"

(1993), investigates human cognitive abilities, employing factor analysis to elucidate the fundamental structures and relationships of cognitive abilities. Cohen's "Statistical Power Analysis for the Behavioral Sciences" (1988) addresses the importance of statistical power analysis in behavioral sciences, explaining how to perform this analysis and the significance of evaluating the power of research findings. Linn and Petersen's "Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis" (1985) explored sex differences in spatial abilities, using meta-analysis to examine the emergence and nature of these differences. These three works have made significant contributions to their respective fields.

An analysis of the co-citation network map for journals in spatial ability research revealed a total of 1,330 journals meeting the criteria, with notable prominence given to Science, PLOS One, Nature, Intelligence, Neuropsychologia, and Cognition. High impact factors, publication of studies across a variety of topics, a rigorous peer review process, and collaborations involving international authors characterize these journals.

An analysis of the co-citation network map of authors in spatial ability research highlights Mary Hegarty as a prominent figure. Hegarty has inspired many researchers in the field of spatial ability through her extensive work in the field. Her in-depth investigations have introduced new perspectives on spatial thinking and visualization, paving the way for significant discoveries in these areas. Hegarty's research has contributed to a broad scientific discussion and advancements in the field of spatial ability.

In conclusion, this study presents a bibliometric analysis of spatial ability research published in the Scopus database from 1939 to the present. A limitation of this study is that it exclusively examined the Scopus database. Researchers may build upon this work by exploring other databases beyond Scopus and conducting more comprehensive bibliometric analyses of spatial ability or related topics. It is anticipated that this research will serve as a valuable data source and provide detailed insights for those interested in the subject.

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An Examination of Middle School Students' Mathematical Bullying Victimization Levels in Relation to Socio-Demographic Variables

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Abstract

This study aimed to examine mathematical bullying victimization among middle school students and its relationship with socio-demographic variables using the Mathematical Bullying Victimization Scale (MBV-S). The sample consisted of 493 middle school students selected using a disproportionate stratified sampling method from five different schools in Konya, Türkiye, during the spring semester of the 2021-2022 academic year. Data were collected using the relational screening model and analyzed with nonparametric statistical methods. The results showed that female students were more frequently subjected to mathematical bullying compared to males. No significant differences were found in MBV-S scores based on grade levels. However, the analysis of school types revealed that students in girls-only religious middle schools experienced higher levels of mathematical bullying than students in other types of schools. Additionally, students with below-average mathematics achievement were more likely to be victims of mathematical bullying, whereas students with above-average achievement reported lower levels of victimization. The findings highlight the importance of developing strategies to address mathematical bullying that consider students' mathematical abilities and social dynamics. Supportive and inclusive environments should be prioritized, particularly for students with low achievement and those in specific school settings.

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Introduction

It is evident that the role of mathematics in learning processes demonstrates the impact of affective factors on mathematical success. Mathematics occupies a privileged position among school subjects in many countries (Wang, 2006; Li & Li, 2008). The necessity of mathematics for daily life skills (Wininger et al., 2014) and the perception of mathematics as a fundamental course for achieving academic and professional goals (Chiu & Klassen, 2010) are the primary reasons for this. Furthermore, mathematics serves as a filter for educational and career opportunities (Leder et al., 2002). It is notable that approximately 90% of new job roles require mathematical abilities at a level above a high school education (NCTM, 2004). Besides, the mathematical performance of students is a significant factor in determining the role of countries in the high-tech sector and their international competitiveness (OECD, 2007). However, individuals outside of mathematics commonly perceive it as a complex and enigmatic discipline (Furinghetti, 1993; Sam & Ernest, 1999). This has resulted in the portrayal of mathematicians in popular culture, such as cinema, as geniuses navigating intricate symbolic realms (Mulcare, 2008). However, the common perception that mathematics is solely about calculation and is only achievable by those with high intelligence has a negative impact on individuals and children in society.

The influence of emotional factors on fear of mathematics represents a significant area of research. As highlighted by Beswick (2006), the environment and individuals play a significant role in influencing attitudes towards mathematics, either positively or negatively. It has been reported that a child's fear of mathematics and negative attitudes towards the subject are influenced by the parents' level of confidence in their own mathematical abilities. Martínez-Sierra and García González (2016) showed that emotional factors trigger fear of mathematics and that successful students are effective in increasing this fear. The common belief that mathematics requires only a superior intellectual ability causes some students to see themselves as inadequate and to regard more successful students in a superior position (Chestnut et al., 2018).

The way in which mathematics is perceived within society can lead to the development of power imbalances among students. The perception that individuals with high levels of mathematical achievement have a superiority over other students may also negatively affect the way teachers interact with students with low levels of achievement. This may result in the emergence of a hierarchical structure among the students, potentially leading those with advanced mathematical abilities to use this advantage as a means of psychological pressure on their peers. Mathematical power is defined as the ability to effectively utilise mathematical relationships and logical inferences (Ryan, 1998). It has been reported that mathematical power boosts students' self-confidence and is associated with mathematical achievement (Rachlin, 1998).

Bullying refers to systematic aggressive behaviour towards the victim resulting from power imbalances between individuals. These types of behaviour can be observed both between individuals and within the dynamics of a group (Olweus, 1993; Smith & Sharp, 1994). The most important characteristics of bullying are intentionality, repetition, and power imbalance (Olweus, 1999). The term "intentionality" refers to the conscious intention to cause harm. The concept of "repetitions" describes the continuity of the behaviours in question. The term "power imbalance" highlights the existence of physical, social, or psychological inequalities between the bully and the victim.

Physical bullying can be defined as direct physical attacks and threats against the victims, whereas verbal bullying refers to the use of verbal attacks such as ridicule or insults (Hawker & Boulton, 2000). Emotional bullying comprises social exclusion or discrediting of the individual (Crick & Bigbee, 1998). Cyberbullying has become an increasingly widespread problem with aggressive behaviours carried out through digital platforms (Willard, 2005). The impact of bullying on individuals goes beyond the psychological and social aspects, with a negative effect on academic performance. It is common for individuals who have been bullied to present with a range of psychological issues, including loss of self-confidence, stress, anxiety, loneliness and depression (Kapcı, 2004). Victims also experience difficulties in their friendly relations and are exposed to social isolation (Demir & Küçük, 2020). Academically, bullying decreases students' motivation and leads to a decrease in achievement levels (Boulton & Underwood, 1992).

The long-term effects of bullying not only affect the victims but also lead to various social and mental health problems for the individuals who engage in bullying behaviour. The studies reveal that bullies may be more likely to engage in criminal behaviours in the future and may show a lack of empathy development skills (Olweus, 1999). These results indicate that bullying not only causes short-term effects on individuals but also may cause long-term social and psychological consequences.

It has been reported that the prevalence of bullying among students in Türkiye is significantly higher than in other countries (Buluç, 2014). In this context, incidents of bullying in school environments should not be overlooked. Studies have shown that students who are not exposed to bullying in schools have a higher mathematical achievement (Akyüz, 2014; Buluç, 2014; Ponzo, 2013; Sarı et al., 2017; Yavuz et al., 2017). This situation shows that students with high levels of mathematical power and achievement may use that power in ways that are considered abusive towards other students. The phenomenon, which was addressed in the study and emerged based on mathematical power, was defined as "mathematical bullying."

Mathematical bullying was first defined theoretically by Küçükgençay (2024) as “one or more students using their mathematical power, mathematics achievement and intellectual ability to intentionally and systematically

continue negative behaviour against an individual or individuals who are weaker in terms of mathematical power and mathematics achievement". Mathematical bullying can also be defined as "systematic abuse of mathematical power within interpersonal relationships". Also, being a victim of mathematical bullying negatively affects students' attitudes towards mathematics and their mathematical self-efficacy perceptions and increases their mathematics anxiety (Küçükgençay, 2024).

This study was conducted to understand the phenomenon of mathematical bullying and to examine the mathematical bullying victimization levels of middle school students in terms of some socio-demographic variables with the Mathematical Bullying Victimization Scale (MBV-S). The study aims to establish a new research area in literature and contribute to an in-depth understanding of the effects of this problem. Accordingly, an answer was sought to the question "Do middle school students' scores obtained from the MBV-S and the sub-dimensions of the scale show a statistically significant difference by gender, grade level, type of school they are enrolled in, and mathematics achievement level?".

Method

Model

The Mathematical Bullying Victimization Scale (MBV-S) scores of middle school students were evaluated in relation to some socio-demographic variables by the research problem. Accordingly, the study was conducted using the relational screening model, which is one of the quantitative research methods. Quantitative research is a type of study that aims to explain the current situation using numerical data (Creswell, 2009). The relational screening model aims to determine whether two or more variables are related to each other (Karasar, 2009). This study analysed the possible relationships between the variables.

Population and Sample

The population of the study consists of all middle school students studying in the central districts of Konya, a metropolitan city located in the Central Anatolia Region of Türkiye, during the spring semester of the 2021-2022 academic year. The sample comprises students from five selected middle schools, which were identified using a disproportionate stratified sampling method. These schools consist of a male religious (imam-hatip) middle school, a female religious middle school, a mixed public middle school in the city centre, a mixed public middle school in rural areas, and a mixed private middle school. One class from the 5th, 6th, 7th, and 8th grades in each school was randomly selected.

The population must first be divided into independent strata according to a descriptive variable in order to use the stratified sampling method (Bernard, 2011). School type was chosen as a descriptive variable in this study. Disproportionate stratification sampling involves selecting equal participants for each stratum, regardless of the representation rates of the strata in the population (Schmidt & Hunter, 2014). The reason why the disproportionate stratified sampling method is preferred is to ensure that each stratum is represented in the study with a significant size (Morgan & Morgan, 2008). Table 1 presents some demographic characteristics of the study group. In the study, the schools were coded as follows: School A, a male religious middle school; School B, a female religious middle school; School C, a private mixed middle school; School D, a mixed public middle school located in the rural areas of the city; and School E, a mixed public middle school located in the city centre.

Table 1. Some demographic data about the study group

School Types	5th Grade		6th Grade		7th Grade		8th Grade		Total
	Female	Male	Female	Male	Female	Male	Female	Male	
School A	0	21	0	22	0	20	0	26	89
School B	30	0	25	0	29	0	27	0	111
School C	6	7	9	10	9	8	14	14	77
School D	17	12	20	10	12	5	17	14	107
School E	12	16	15	14	15	11	14	12	109
Total	65	56	69	56	65	44	72	66	493

Table 1 shows that the study group consisted of 493 students selected from five different schools. 271 of the students participating in the study group are female, and 222 are male. The distribution within the scope of the study aimed to ensure the diversity of the demographic characteristics of the participants.

Data Collection Tools

Personal data form

It consists of a set of questions covering demographic data of middle school students such as gender, grade, school type and end-of-year mathematics grades.

Mathematical Bullying Victimization Scale (MBV-S)

The Mathematical Bullying Victimization Scale (MBV-S) was designated by Küçükgençay (2024) to determine the level of exposure to mathematical bullying among middle school students. The scale was designed in a 5-point Likert format, with each sub-dimension represented by a specific number of items. The scale addresses

mathematical bullying in four fundamental dimensions: the Verbal Mathematics Bullying sub-dimension comprises four items, and Cronbach's alpha coefficient was calculated as 0.76. The sub-dimension of Emotional Mathematics Bullying comprises four items, and Cronbach's alpha coefficient was 0.73. The Physical Mathematics Bullying sub-dimension comprises three items and Cronbach's alpha coefficient for this sub-dimension was 0.71. The Educational Mathematics Bullying sub-dimension comprises three items and Cronbach's alpha coefficient was calculated as 0.70. The Cronbach's alpha reliability coefficient for the entire scale, comprising 14 items in total, was determined to be 0.84, indicating that the scale is a highly reliable measurement tool. The scale does not include any reverse items and the maximum score that can be achieved is 70, while the minimum score is 14. The MBV-S is an effective tool for measuring students' experiences of mathematical bullying in a comprehensive and reliable manner.

Data Analysis

This study investigated whether middle school students' scores on the Victimization of Mathematical Bullying Scale (MBV-S) differ according to certain socio-demographic variables. SPSS 23 software was used to analyse the data obtained to answer the research question. First, the results of the Kolmogorov-Smirnov normality test were used to determine whether or not the collected data were normally distributed. The data groups included in the analysis were found to be not normally distributed. The effect of gender on the mathematical bullying victimization (MBV) and its sub-dimensions was then analysed using the Mann-Whitney U test, which is the non-parametric equivalent of the t-test. The Kruskal-Wallis test, which is the non-parametric equivalent of the one-way ANOVA test, was used to test whether there was a significant effect of grade level, school type and mathematics achievement on mathematical bullying (MBV) and its sub-dimensions. The Mann-Whitney U test, which is the non-parametric equivalent of the independent samples t-test, was used to determine the group from which a significant difference was detected. The alpha level was determined using the Bonferroni correction in the interpretation of the test results. The Bonferroni correction is a commonly used method to adjust the significance level for multiple comparisons to control for the overall type I error rate. This method is used to minimise the possibility of false positive results in multiple-hypothesis testing (Dunn, 1961). The 95% confidence interval level ($\alpha = 0.05$) was divided by the number of hypothesis tests performed to obtain the adjusted p-value. The significance of the results was interpreted according to the corrected p-value.

Data Collection and Ethics

This study was approved by the Ethics Committee of Necmettin Erbakan University Social and Human Sciences Scientific Research Ethics Committee with the letter dated 18.06.2021 and number 2021/367. This article is derived from a section of the doctoral dissertation currently being prepared by the first author under

the supervision of the second author. Scientific ethical values were carefully considered in the research process and ethical principles were used in data collection and analysis. Ethical standards were adopted at all stages of the study.

The necessary permissions were received from the respective institutions, interviews were held with the schools where the research would be carried out and the data collection process was thoroughly planned. The scales and forms to be used in the study were distributed in printed form to the participants in the study group. The application was carried out during one lesson in each class, during which the researcher provided the necessary explanations. Two days before data collection, parental consent forms were distributed to students, and data were only collected from students who had parental consent and volunteered. The whole process was conducted in accordance with ethical rules and the rights of participants were respected.

Results

The Effect of Gender on The MBV Variable

The data for both groups do not follow a normal distribution according to the results of the Kolmogorov-Smirnov normality test ($p < 0.05$). These results indicate that the data should be analysed with non-parametric tests rather than with parametric tests. Therefore, the Mann-Whitney U test was used to proceed with the analysis. Table 2 presents the results of the Mann-Whitney U test to see whether the MBV differs significantly by gender.

Table 2. Mann-Whitney U test results of MBV according to gender

Gender	N	Ranking Average	Ranking Total	Mann-Whitney U	Z	p	Effect Size (r)
Female	271	260.97	70724	26294	-2.408	0.016	-0.108
Male	222	229.94	51047				

Table 2 presents the results of the Mann-Whitney U test analyzing MBV scores according to gender. The test reveals a statistically significant difference between female and male students ($U=26294$, $Z=-2.408$, $p=0.016$, $p<0.05$). The ranking averages indicate that female students (ranking average = 260.97) scored higher on MBV compared to male students (ranking average = 229.94). However, the calculated effect size ($r=-0.108$) suggests a small effect, indicating that while the difference is statistically significant, its practical significance is limited. It was observed that the total MBV scores of female students were higher than those of male students, suggesting that female students are more likely to be victims of mathematics bullying than male students.

The Effect of Grade Level on The MBV Variable

The results of the Kolmogorov-Smirnov normality test indicate that the data are not normally distributed across all grade levels ($p < 0.05$). Therefore, the analysis continued with the Kruskal-Wallis test. Table 3 presents the results of the Kruskal-Wallis test, indicating whether the MBV varies significantly according to the grade levels.

Table 3. The results of the Kruskal-Wallis test of MBV according to grade levels

Grade Level	N	Average	χ^2	df	p
5	121	235.69	3.017	3	0.389
6	125	236.1			
7	138	256.63			
8	109	259.86			

Table 3 presents the results of the Kruskal-Wallis test conducted to analyze the differences in MBV scores across different grade levels. The test statistic, $\chi2=3.017$, with 3 degrees of freedom, indicates that there is no statistically significant difference in MBV scores among the grade levels ($p=0.389$, $p>0.05$). Although the average ranks of MBV scores appear to increase slightly from 5th grade (235.69) to 8th grade (259.86), this difference is not sufficient to reach statistical significance. Therefore, grade level does not appear to have a significant impact on MBV scores in this sample.

The Effect of School Type on The MBV Variable

According to the results of the Kolmogorov-Smirnov normality test**,** the data of other school types ($p < 0.05$) except for School B ($p > 0.05$) do not show a normal distribution. Nonparametric tests should be preferred instead of parametric tests in comparing the averages of the groups in cases where the normality assumption is not met. Therefore, the Kruskal-Wallis test was utilized in the analysis. Table 4 presents the results of the Kruskal-Wallis test, indicating whether the MBV varies significantly according to the school types.

Table 4. The results of the Kruskal-Wallis test of MBV according to school types

School	N	Average	χ^2	df	p
School A	89	241.15			
School B	111	318.43			
School C	77	217.74	37.474	4	0.000
School D	107	220.99			
School E	109	225.24			

As can be seen in Table 4, a significant difference between the average scores of participants studying in different school types is observed ($p < 0.05$). Since the school variable was divided into five categories, the Mann-Whitney U test was used to compare $C\left(\frac{5}{2}\right) = 10$. The alpha level in the interpretation of the test results was corrected with Bonferroni correction and the value of 0.05 was divided by the number of comparisons. Accordingly, the alpha level of 0.005 was used as the criterion for interpreting the results of the Mann-Whitney U test. Table 5 shows the results of the Mann-Whitney U tests for the comparisons between school types.

Table 5. Mann-Whitney U test results concerning the comparisons of MBV according to school types

School	N	Ranking Average	Ranking Total	Mann-Whitney U	Z	p	Effect Size (r)
School A	89	82.63	7354	3349	-3.913	**0.000***	-0,277
School B	111	114.83	12746				
School A	89	87.17	7758	3100	-1.058	0.290	-0,082
School C	77	79.26	6103				
School A	89	103,5	9211.5	4316.5	-1.127	0.260	-0,08
School D	107	94.34	10094.5				
School A	89	102.85	9153.5	4552.5	-0.744	0.457	-0,053
School E	109	96.77	10547.5				
School B	111	109.54	12158.5	2604.5	-4.552	**0.000***	-0,332
School C	77	72.82	5607.5				
School B	111	130.41	14476	3617	-4.990	**0.000***	-0,338
School D	107	87.8	9395				
School B	111	131.65	14613.5	3701.5	-4.978	**0.000***	-0,336
School E	109	88.96	9696.5				
School C	77	91,14	7017.5	4014.5	-0.295	0.768	-0,022
School D	107	93,48	10002.5				
School C	77	91.52	7047	4044	-0.422	0.673	-0,031
School E	109	94.90	10344				
School D	107	107.36	11487.5	5709.5	-0.266	0.790	-0,018
School E	109	109.62	11948.5				

Table 5 shows the Mann-Whitney U test results comparing MBV scores across different school types. A statistically significant difference was observed between School A and School B, with ranking averages of 82.63 and 114.83, respectively ($Z = -3.913$, $p = 0.000$, $r = -0.277$). This small-to-moderate effect size suggests that students in School B have higher MBV scores compared to those in School A.

Similarly, significant differences were found between School B and other school types. When comparing School B and School C, the ranking averages were 109.54 and 72.82, respectively (Z = -4.552, p = 0.000, r = -0.332), indicating a moderate effect size and a clear advantage for School B. A significant difference also emerged between School B and School D, with ranking averages of 130.41 and 87.80, respectively (Z = -4.990, p = 0.000, r = -0.338). Similarly, the comparison between School B and School E revealed ranking averages of 131.65 and 88.96, respectively (Z = -4.978, p = 0.000, r = -0.336), again demonstrating a moderate effect size.

The findings reveal that students attending religious middle schools exclusively for girls achieve higher MBV scores compared to their peers in other school types. The moderate effect sizes observed across multiple comparisons underscore the significant impact of school type on MBV outcomes. Moreover, the analysis indicates that students in these all-girls religious middle schools are more likely to experience mathematical bullying compared to students in other school settings.

The Effect of Mathematics Achievement Levels on The MBV Variable

According to the results of the Kolmogorov-Smirnov normality test, 0-44, 45-54 and 55-69 grades show normal distribution ($p < 0.05$), but 70-84 and 85-100 grades do not show normal distribution ($p > 0.05$). As all groups demonstrated a lack of normal distribution, the analysis proceeded with the Kruskal-Wallis test. Table 6 shows the results of the Kruskal-Wallis test on whether the MBV differed significantly according to the mathematics achievement levels.

Table 6. The results of the Kruskal-Wallis test of MBV according to mathematics achievement levels.

Achievement Grade	N	Average	χ^2	df	p
0-44	38	307.59			
45-54	66	321.67			
55-69	75	277.45	49.499	4	0.000
70-84	106	246.04			
85-100	208	201.75			

The data in Table 6 indicate that there is a significant difference between the averages of the achievement grades ($p < 0.05$). Since the achievement grade was divided into five categories, the Mann-Whitney U test was used to compare $C\left(\frac{5}{2}\right) = 10$. The alpha level in the interpretation of the test results was corrected with Bonferroni correction and the value of 0.05 was divided by the number of comparisons. Accordingly, $\alpha = 0.005$ was used as the criterion for interpreting the results of the Mann-Whitney U test. Table 7 shows the results of the Mann-Whitney U tests for the comparisons between mathematics achievement levels.

Table 7. Mann-Whitney U test results concerning the comparisons of MBV according to mathematics achievement levels.

Achievement Grade	N	Ranking Average	Ranking Total	Mann-Whitney U	Z	p	Effect Size (r)
0-44	38	51.18	1945	1204	-0.338	0.735	-0.033
45-54	66	53.26	3515				
0-44	38	62.38	2370,5	1220.5	-1.244	0.214	-0.117
55-69	75	54.27	4070,5				
0-44	38	85.97	3267	1502	-2.322	0.020	-0.194
70-84	106	67.67	7173				
0-44	38	166.55	6329	2316	-4.061	**0.000***	-0.259
85-100	208	115.63	24052				
45-54	66	77.71	5129	2032	-1.832	0.067	-0.154
55-69	75	65.09	4882				
45-54	66	102.93	6793,5	2413,5	-3.418	**0.001***	-0.261
70-84	106	76.27	8084,5				
45-54	66	188.27	12425,5	3513,5	-5,980	**0.000***	-0.361
85-100	208	121.39	25249,5				
55-69	75	98.12	7359	3441	-1.539	0.124	-0.114
70-84	106	85.96	9112				
55-69	75	173.96	13047	5403	-3.949	**0.000***	-0.235
85-100	208	130.48	27139				
70-84	106	176.64	18724	8995	-2.670	0.008	-0.151
85-100	208	147.75	30731				

The Mann-Whitney U test results in Table 7 reveal significant differences in MBV rankings across mathematics achievement levels at $p < 0.005$. A statistically significant difference was found between the 0–44 and 85–100 achievement groups ($U = 2316$, $Z = -4.061$, $p = 0.000$, $r = -0.259$). The 85–100 group exhibited lower rankings (average = 115.63) compared to the 0–44 group (average = 166.55), indicating that students in the higher achievement group experience fewer MBV-related issues. The effect size ($r = -0.259$) represents a small-to-medium statistical significance.

Similarly, significant differences were observed between the 45–54 and 70–84 groups ($U = 2413.5$, $Z = -3.418$, $p = 0.001$, $r = -0.261$) and between the 45–54 and 85–100 groups ($U = 3513.5$, $Z = -5.980$, $p = 0.000$, $r = -0.361$). In both cases, the higher achievement groups (70–84 and 85–100) displayed lower rankings, reflecting fewer MBV experiences. The effect sizes ($r = -0.261$ and $r = -0.361$) indicate small-to-medium and medium impacts, respectively. Additionally, a significant difference was found between the 55–69 and 85–100 achievement groups ($U = 5403$, $Z = -3.949$, $p = 0.000$, $r = -0.235$). The 85–100 group had lower rankings

(average = 130.48) compared to the 55–69 group (average = 173.96), suggesting fewer MBV-related challenges among the highest achievers. The effect size (r = -0.235) is small-to-medium.

These results show that students with higher mathematics achievement are victims of mathematical bullying less than other achievement groups. Therefore, it can be said that those with higher mathematical achievement are more resilient to MBV.

Discussion and Conclusion

This study analysed whether the scores obtained from the MBV-S developed by (Küçükgençay, 2024) and the sub-dimensions of the scale showed significant differences according to the variables of gender, grade, school type and mathematics achievement level of middle school students. This study was conducted with certain assumptions and limitations. The data collected with the measurement tools in the study were assumed to reflect reality. The study was conducted during the spring semester of the 2021-2022 academic year and was limited to the 5th, 6th, 7th and 8th-grade students studying in five middle schools selected using the disproportionate stratified sampling method from the central districts of a metropolitan city in the Central Anatolia Region of Türkiye. The study was also limited to the data collected from the personal information form and mathematical bullying victimization scales.

The results revealed that the levels of mathematical bullying victimization differed significantly by gender ($p < 0.05$). Accordingly, female students received higher MBV scores than male students and had more intense experiences in this regard. The fact that these experiences are more intense among female students suggests that they encounter more negativity in the mathematics education process. The fact that female students have higher overall MBV-S scores indicates that this group has more bullying experiences. For example, Olweus and Endresen (1998) reported that empathy tendencies of female students increased after the age of ten, whereas this tendency decreased in male students. Similarly, the results of Menesini et al. (1997) show that female students are more exposed to bullying and have a higher sense of loneliness. The study by Paul and Cillesen (2003) states that female students are more deeply affected by bullying experiences due to their higher levels of depression, anxiety and negative self-perceptions.

The analyses conducted according to the grade levels revealed that there was no significant difference in the scores of MBV-S ($p > 0.05$). This reveals that students were exposed to this type of bullying at similar levels. The fact that there was no significant difference in terms of grade level in the analysis of the MBV reveals that bullying, at least at the middle school level, is not specific to a certain age and grade level, but can occur as a result of the social dynamics that students experience in general. Behaviours such as verbal, physical and

emotional mathematical bullying are likely to be shaped by factors such as social interactions of students in the classroom, peer groups and the general school environment rather than by the grade level. The literature shows various results that bullying types may vary according to age and grade level (Batsche & Knoff, 1994; Hanish & Guerra, 2000). Satan (2006) and Çankaya (2011) reported that physical bullying is more likely to be replaced by emotional bullying in older age groups. However, the fact that there was no significant difference between the grade levels in terms of mathematical bullying in this study suggests that it is because the types of mathematical bullying follow different dynamics. The fact that mathematical bullying does not show a significant difference according to grade level indicates that this type of bullying is experienced in similar social interactions regardless of the age or grade level of the students.

The results of the study show that students from religious middle schools, where only female students were educated, had higher levels of mathematical bullying experiences compared to students from other schools ($p < 0.005$). These findings indicate that social and cultural factors may influence the experiences of female students in single-gender schools concerning mathematical bullying. The study of Menesini et al. (1997) finds that female students are more likely to be victims of bullying and have more intense feelings of loneliness, while the study of Paul and Cillesen (2003) states that girls' high levels of depression and anxiety and their negative self-perceptions lead them to be more deeply affected by bullying experiences. The fact that female students had higher levels of MBV, which is another result of the study, is consistent with this situation.

Although single-gender schools have been found to have fewer disciplinary problems and a greater focus on academic achievement (LePore & Warren, 1997), it can be assumed that this situation may increase the pressure on female students to succeed in single-gender schools. A single-gender education environment may lead to expectations based on gender roles and a limited school structure. Traditional social norms, in particular, may cause a misconception that female students are less successful than male students in areas such as mathematics (Croizet et al., 2004; Good et al., 2003; Johns et al., 2005; Schmader & Johns, 2003). Warrington and Younger (2001) found out that one of the main advantages of single-gender classrooms is that teachers can adapt their teaching methods by considering the different learning styles of male and female students. However, it can be questioned whether the teachers are really fair and caring in their relationships with the students during this adaptation process. Although it is possible to use different methods depending on the needs of the students, this situation is thought to have the risk of reinforcing prejudiced attitudes of teachers and showing discriminatory behaviours against some students.

According to the results of the study, the relationship between mathematical bullying and mathematics achievement showed that students with high achievement grades had lower levels of mathematical bullying experience ($p < 0.005$). Significant differences were found between the groups of students with mathematics

grades between 85-100 and those with grades 0-44, 45-54 and 55-69, and it was concluded that these students were less exposed to mathematical bullying. A significant difference was also found between students with grades between 70-84 and those with grades between 45-54. This situation points out that students with low mathematics achievement grades experience more mathematical bullying than those with high achievement grades. In general, it was observed that as mathematics achievement increased, the rate of being a victim of mathematics bullying decreased. This suggests that students with high achievement levels usually take advantage of positive social perceptions such as respect and recognition by their peers, and therefore experience less bullying.

It is noteworthy that students with high mathematics achievement are generally less likely to experience mathematics bullying, while students with low achievement are more likely to be victims of this type of bullying. The results of the study reveal the relationship between mathematical bullying and mathematical power and also highlight the links between the basic dynamics of mathematical bullying and the concept of mathematical power. Given that mathematical bullying is shaped by the abuse of mathematical power differentials, it explains why students with high mathematical power are less likely to experience this type of bullying. Although mathematical power and mathematical achievement are defined as different concepts, high grades in mathematics may lead students to perceive themselves as having high mathematical power. Similarly, Ev-Çimen (2008) found that students associated the concept of mathematical power with abilities such as performing mental operations, solving difficult problems, and superior performance in mathematics.

Many studies emphasise that individuals who are bullied consist of individuals who are powerless or perceive themselves to be powerless (Bitney & Title, 1997; Mellor, 1997; Olweus, 1999; Pişkin et al., 2011; Sarıbeyoğlu, 2007; Yıldırım, 2003). Mathematical power includes mathematical thinking, problem-solving and the ability to combine these skills with effective communication (NCTM, 2004). This power can become an important element in determining an individual's social status in the classroom. Students who are perceived as having high mathematical power may avoid being targets of mathematical bullying because of their status.

Students with high achievement grades experienced less bullying in emotional, physical, verbal and instructional types of mathematical bullying. This can be interpreted as a reflection of how perceived mathematical power differences in the classroom shape the social balance and the influence of socio-mathematical norms. Cobb and Yackel (1996) recognised norms of teacher-student interactions, being a general rule in the classroom microculture, as an important phenomenon in the mathematical learning process. Sociomathematical norms are described as rules that are accepted by students and teachers in mathematical discussions and group work, and which guide mathematical interactions in the classroom (Cobb & Yackel, 1996). These norms can play an important role in the development of the social structure in the classroom by

determining the mathematical power dynamics among students. In this context, students considered to have high mathematical power may have a strong position in social relationships within the class, while students with low levels of mathematical power may be more likely to feel the negative effects of this power imbalance. Considering that mathematical power includes not only mathematical skills but also some affective characteristics of students (Gündoğdu & Kurtuluş, 2016), students with high mathematical power may be more socially empowered in mathematics lessons and protected from mathematical bullying thanks to these skills. However, for students with low levels of mathematical power, this situation may be the opposite.

Recommendations

The following recommendations have been developed for researchers, practitioners and policymakers considering the results and limitations of the study:

Further studies on mathematical bullying should be conducted involving different school types and age groups. The effects of factors such as school environment, teacher behaviour, and the activities of counselling services on the experiences of students with mathematical bullying should be evaluated in this context. Studies should be extended to investigate the effects of mathematical bullying in different socio-economic groups. Future studies of this kind may contribute to a better understanding of whether mathematical bullying is a context-specific or universal phenomenon.

Studies examining the effects of gender factors on mathematical bullying should be carried out. These studies may contribute to the development of more effective intervention programmes by revealing the differences in experiences between male and female students.

Individual in-depth interviews with students who have been the victims of mathematical bullying can provide valuable data to understand the effects of this bullying at the individual level and how students perceive this situation. It is also necessary to conduct focus group studies with groups of students from different demographic characteristics to examine in depth how mathematical bullying is shaped in the social context and the impact of group dynamics on this process.

Qualitative studies to be conducted with teachers, school administrators and counselling services can provide a comprehensive perspective on the perception of mathematical bullying in an educational environment and intervention methods for such situations.

Studies adopting a mixed-methods approach (qualitative and quantitative), should be conducted to understand the relationship between mathematical bullying and peer bullying. These studies can contribute to the development of preventive strategies by identifying the common and different dynamics of both types of bullying.

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Measure of online indices among tertiary institution students in Lagos, Nigeria

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Abstract

Online indices can serve as a gauge of students' digital readiness and proficiency in navigating digital learning environments. Assessing students' familiarity with digital tools, online communication platforms, and information literacy skills can help institutions tailor support services and training programs to meet students' needs. Hopefully, it is expected that data generated can inform instructional design and course delivery strategies that would enhance the online learning experience and promote student success. Hence, this research work assesses the extent of undergraduate students' response to ten online indices such as attendance, attention, regularity, distraction and so on, using an adapted questionnaire. Answers were provided to three research questions raised in the study. Data generated was analyzed using descriptive statistics of frequency counts, percentages, mean and Standard deviation. Findings revealed that undergraduate students are ready to navigate digital learning as seen in their engagement in online learning and agreement to convenience in attending online classes among others, though it is established that they face technical issues during online classes. It is therefore recommended that tertiary institutions can leverage on undergraduates' digital literacy and accept the change for effective technological integration.

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Introduction

The method of teaching from the period education was brought to Nigeria by the missionaries has been conventional, where lecturers and students see and interact. In this method, lecturer visits the classroom where students are sited in preparation for the lesson. Though it has been asserted that learning can occur in many contexts, and that the learning environment can be structured or informal as it complements each other (Eziyi, Oluwole & Owoseni, 2017). With the advent of technology in 1990s, technology has been seen to have the ability to change traditional teaching and learning processes; the ability to eliminate geographic and temporal barriers to education and significantly expand access to lifelong learning. By this students no longer need to be physically present in the same area at the same time in order to get instruction from an instructor. Fundamentally therefore, new technology has proven to have the potential to influence how institutions of higher education are seen. Technology has been integrated into education and training, which informed digital knowledge.

Digital learning refers to the use of digital technologies, tools and resources to support and enhance the learning process. In this case the facilitator taught electronically via the internet, intranets or multimedia platforms such as CD-ROMs or DVDs. In Smart & Cappel (2006) view, it involves the integration of digital elements such as online courses and tutorial, digital textbooks and multimedia content, virtual classrooms and webinars, and so on. Many users have access to direct internet connections and synchronous interactive settings, self-paced independent study mechanisms, asynchronous interactive sessions.

Digital learning has grown tremendously over the past years. Advances in technology since the 1990s have given rise to an increased use of web-based tools in distance education, and recently, many institutions of higher learning offer digital instruction with integrated web-based instructional tools known as Digital Learning System (DLS). The system has absolutely moved into higher education with novel additional programs - the blended synchronic learning (digital and conventional approaches) mode, gaining and developing trend in higher education. With fast expansion of global education market, several universities have increased their transnational education offer, like blended and distance learning (Bali & Liu, 2018).

Digital learning is seen to lack interactivity vis-à-vis traditional learning. It has been promoted as being more cost-effective and practical than conventional educational environments, and as providing opportunities for more learners to continue their education. Rodriguez, Klaus & Milner (2008) agreed that sustaining enrolment in higher education will depend upon students' learning experiences and sensitivity in digital learning system or conventional learning environment. This is a pointer that higher education institution is approaching a phase

where physical site equipped with classrooms and residence halls where students congregate to pursue higher education is less emphasised.

Nkedishu, Egwunyenga & Nwaorgu (2021) opined that significant forces are forcing higher education to embrace this new technology. These forces among others include: Globalization's rapid growth, which is eroding international borders and transforming the business world and also expanding the potential reach of schools and institutions. With the advancement of superior communication technology, institutions of higher education are no longer confined by their local student markets or instructional resources. Similarly, the growing need for opportunities for lifelong learning in order to keep current with social, economic, and technological advances creates a demand for accessible alternatives to traditional on-campus, real-time training. Additionally, competition among institutions of higher education fosters technological innovation inside colleges and universities. To avoid being eclipsed by competitors, many institutions participate actively in a technology "arms race" that requires rapid adoption of new technological developments as they become available. The alternative is to fall behind other universities in the race for the same students, faculty, and funding.

Online learning affords students access to a choice of tools that complement the job at hand and allow them to gain a better grasp of topic. Acceptance of change is a must for effective technological integration. Integrated technology is when technology works well with the syllabus or teaching strategies (Rathore & Sonawat, 2015). Integrated technology is always developing; it's a never-ending process of learning. Computers, multi-touch screens, mobile devices, audio recorders, e-book readers, games, light tables, are examples of technological tools engaged in learning. Thus, rather than being an extra layer in the classroom, technology is interwoven in the lesson plan and pedagogy. In this technique, teachers plan activities and students utilize technology to create their own. For example, students utilize technology to gather information, arrange it, and display it using computer apps. The instructor is a facilitator and the student a learner constructor. According to Charania (2011) this method promotes student usage of technology, genuine assessments and activities involving technology in the classroom.

In schools, classrooms, and among teachers and students, there is a substantial body of research on the use of digital technology. However, most of these studies are narrow in scope, focusing on only one or two aspects of education and technology (for example, classroom cases or teacher and student technical competence), thereby isolating the object of study from the larger context of a school (Liisa & Minna, 2018). According to Freitas and Paredes (2018), technology utilized in digital learning focuses more on student-centred pedagogies that go beyond the simple transfer of information, although via new and flashy channels (video lectures, fancy-designed virtual platforms, etc.). Despite the promise of technology, its integration into higher education has

been everything but smooth or rapid. However, in 2020 due to COVID-19 pandemic restrictions, traditional classroom teaching in many institutions was shifted to online teaching. Students have to go online to attend, participate and get involved in the classroom, which is not physically assessable to them.

However, tertiary institutions embrace of online learning comes with its challenges among which are Student's understanding of course content; paying attention to lectures; convenience and regularity in attending classes; clearing doubts during the class; facing technical issues during online classes; students attending and sticking to the time table of traditional classes as compared to online classes; as well as students interaction and engagement in online classes. Hence, this study has been conducted to empirically ascertain the extent of undergraduates' response to these online indices in Lagos – Nigeria.

Research Questions

1. What is the extent of undergraduate students' response to the ten online indices?
2. How ready are undergraduate students in navigating digital learning environment?
3. How does undergraduate students' readiness to navigate digital learning environment vary by demographic factors such as age, gender, field of study, level of study and ethnic affiliation?

Method

Research Design

A qualitative approach using an online survey design of an ex-post facto type was adopted for the study. The target population comprises all undergraduate students in Lagos - Nigeria. Online survey questionnaire on google forms were sent to different undergraduate Whatsapp platforms, from where Three hundred (300) completely filled responses were selected. These constitute the sample for the study.

Instrumentation

The main instrument employed in the study was an adapted questionnaire comprising of two sections: Section A consists of profile of the respondents in the study; Section B was a ten (10) items statement that measures the extent of respondents response to the online indices considered in the study.

Administration of Instrument

The Instrument was administered and retrieved with the assistance of students and colleagues compelled to send the online survey questionnaire to different students' whatsapp platform. It was sent to more than Three hundred (300) undergraduates across Lagos - Nigeria.

Data Analysis

The data generated were analysed using frequency count, percentages, mean and standard deviation.

Result

Research Question 1: What is the extent of undergraduate students' response to the ten online indices

Table 1. Frequency, percentage, mean and standard deviation of extent of undergraduate students' response to the ten online indices

S/N	Statement	SA	A	D	SD	Mean	Std. Dev.
1	Online classes provide better understanding of course content	25 (8.33)	100 (33.34)	160 (53.33)	15 (5.00)	2.45	0.12
2	It is easier to pay attention to lectures in online classes	45 (15.00)	65 (21.67)	160 (53.33)	30 (10.00)	2.42	0.15
3	Online classes are not convenient to attend	40 (13.33)	130 (43.33)	110 (36.67)	20 (6.67)	2.37	0.20
4	It is not easier to clear doubts through online discussions	50 (16.67)	160 (53.33)	75 (25.00)	15 (5.00)	2.18	0.39
5	Students face technical issues during online classes	135 (45.00)	135 (45.00)	20 (6.67)	10 (3.33)	3.32	0.75
6	Students are more likely to attend online classes than traditional classes	55 (18.33)	100 (33.33)	110 (36.67)	35 (11.67)	2.58	0.01
7	It is not easier to get distracted during online classes than during traditional classes	25 (8.33)	70 (23.33)	130 (43.33)	75 (25.00)	2.85	0.28
8	Students are more likely to stick to the time table of traditional classes as compared to online classes	100 (33.34)	135 (45.00)	55 (18.33)	10 (3.33)	3.08	0.51
9	Students do not miss social interaction with peers and teachers in case of online classes	55 (18.33)	125 (41.67)	110 (36.67)	10 (3.33)	2.25	0.32
10	Lack of face to face communication does not make online classes less engaging	60 (20.00)	140 (46.67)	85 (28.33)	15 (5.00)	2.18	0.39
	Weighted Average			**2.57**			

Table 1 revealed the extent of undergraduate students' response to the ten online indices such as attendance, attention, regularity, distraction and so on. It shows undergraduates agreement to Online classes providing

better understanding of course content ($\bar{X}$ = 2.45); being easier to pay attention to lectures in online classes ($\bar{X}$ = 2.42); Online classes not convenient to attend ($\bar{X}$ = 2.37); not easy to clear doubts through online reception ($\bar{X}$ = 2.18); students facing technical issues during online classes ($\bar{X}$ = 3.32); students more likely to attend online classes than traditional classes ($\bar{X}$ = 2.58); getting distracted during online classes than traditional classes ($\bar{X}$ = 2.85); students more likely to stick to time table of traditional classes as compared to online classes ($\bar{X}$ = 3.08); students not missing social interaction with peers and teachers in case of online classes ($\bar{X}$ = 2.25) and lack of face to face communication not making online classes less engaging ($\bar{X}$ = 2.18). Weighted average value of 2.57 ascertained the extent of undergraduate students' understanding of course content; paying attention to lectures; convenience and regularity in attending classes; clearing doubts during the class; facing technical issues during online classes; students attending and sticking to the time table of traditional classes as compared to online classes; as well as students interaction and engagement in online classes.

Research Question 2: How ready are undergraduate students in navigating digital learning environment?

Students' digital readiness and proficiency in navigating digital learning environment can be measured by the followings among others:

1. Ownership of smartphones/laptops
2. Presence on social media
3. Participation in online learning platform
4. Frequency of online interaction
5. Ability to use digital device

Without missing words, a higher percentage of Nigerian undergraduates (nearly 100%) fulfilled the five variables listed above. Due to COVID-19 pandemic restrictions, traditional classroom teaching in Nigeria was shifted to online teaching. Students have to go online to attend, participate and get involved in the classroom, which is not physically assessable to them then. Undergraduates that did not have android phones prior to this period had no choice but to get one to enable him/her participate in online classes. Also, for a long period, Joint Admission and Matriculation Board examination and 100level examinations in most institutions are Computer-based. Hence, it can be affirmed that undergraduate students are apt to be ready in navigating digital learning environment.

Research Question 3: How does undergraduate students' readiness to navigate digital learning environment vary by demographic factors such as age, gender, field of study, level of study and ethnic affiliation?

Table 2. Demographic factors of the Three Hundred (300) respondents in the study

S/N	Variables	Frequency	Percentage
1	Age: 15 – 19years	70	23.33
	20 – 25years	160	53.33
	26 – 30years	25	8.33
	31 – 40years	45	15.01
2	Gender: Male	125	41.67
	Female	175	58.33
3	Field of Study: Sciences	185	61.67
	Arts	25	8.33
	Social sciences	60	20.00
	Vocational	30	10.00
4	Level of Study: 200Level	140	46.67
	300Level	90	30.00
	400Level	70	23.33
5	Ethnic Affiliation: Yoruba	260	86.67
	Igbo	25	8.33
	Hausa	15	5.00

Table 2 revealed how undergraduate students' readiness to navigate learning environment varied by demographic factors such as age, gender, field of study and ethnic affiliation. It shows that 23.33% of the respondents are in the age bracket 15 – 19years, 53.33% are in the age bracket 20 – 25years, 8.33% are in the age bracket 26 – 30years, and the remaining 15.01% are in the age bracket 31 - 40years. The highest number of respondents falls in the age bracket 20 -25years, which happens to represent bulk of persons in the digital age. 41.67% of the respondents are male, while the remaining 58.33% are female. 61.67% are studying Science-related courses, 8.33% are studying Arts-related courses, 20% are studying Social science-related courses and the remaining 10% are studying Vocational courses. 86.67% are from Yoruba ethnic affiliation, 8.33% are from Igbo ethnic affiliation and the remaining 5% are from Hausa ethnic affiliation.

Graphical representation as shown below:

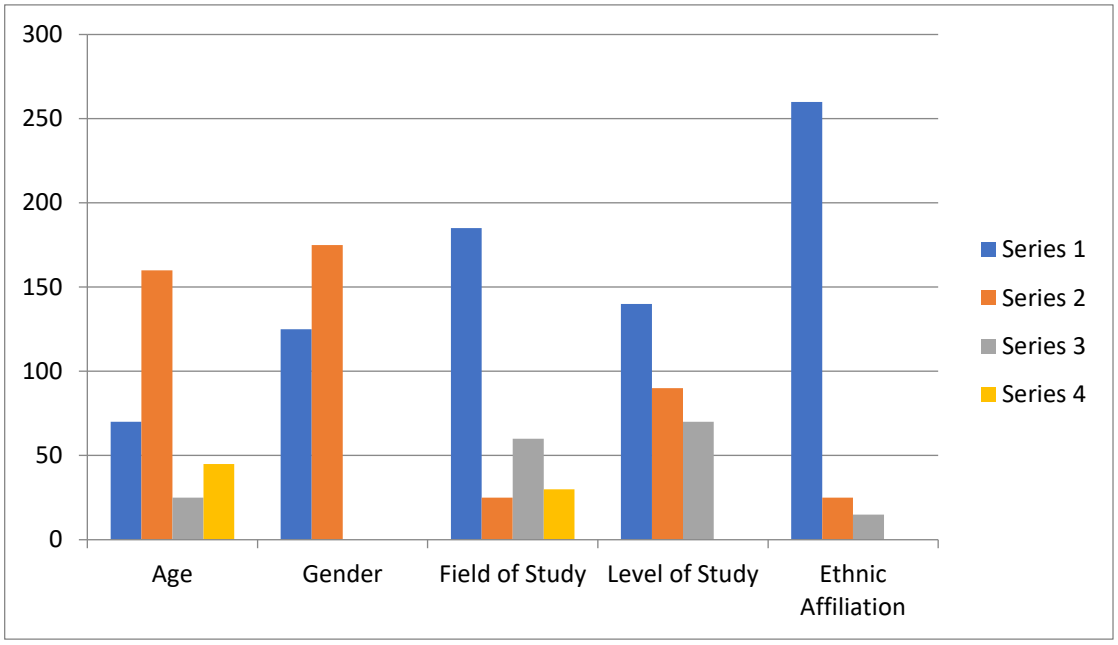

Figure 1. Bar chart description of respondents in the study

Figure 1 revealed that the highest number of respondents in the study falls in the age bracket 20 - 25years; the greatest number of the respondents being female; and the highest number studying science-related courses. A good number are in their second year of study at the University and majority of them are from Yoruba ethnic affiliation.

Discussion

This study tries to establish the extent of undergraduate students' agreement to online classes providing better understanding of course content; making it easier to pay attention to lectures; not being convenience and irregularity in attending online classes; not being easy to clear doubts during the class; not making peers and teachers miss social interaction; and does not make classes less engaging. The mean value for each of these items being less than 2.5, by implication is close to saying that the students disagree to preference of online classes over traditional classes. Since the current trend in higher institutions is blended synchronic learning, more needed to be done to assist undergraduates navigate digital learning environment. At the same time, greater agreement to students was facing technical issues during online classes, which could be as a result of power failure, network disruption, and faulty equipment and so on; students likely attending online classes more and sticking to the time table of traditional classes as compared to online classes. The mean value for each of these items being greater than 2.5, by implication affirms that these indices need to be addressed in promoting online classes.

Information gathered revealed that the highest number of respondents in the study falls in the age bracket 20 - 25years, which capture the average age of present day undergraduates in Nigeria; the greatest number of the respondents being female; and the highest number studying science-related courses. A good number are in their second year of study at the University and majority of them are from Yoruba ethnic affiliation. Also, the result established undergraduate students' readiness to navigate learning environment, since all undergraduates engaged in the study were able to access google forms to be able to participate in the study. Hardly would you meet any undergraduate student that does not have an android phone or laptop. A good number of them are learning digital skills that are required for global competitiveness.

The findings are in consonance with outcomes of various online related studies such as: Jaggars & Xu (2016) study on Online Engagement indicators such as participation rates, discussion forum activity and course completion; and students' academic performance in online courses which found out that active engagement is important for promoting student success in digital learning environment. Afolabi & Otubanjo (2014) study on impact of the internet on academic performance of students in tertiary institution in Nigeria, found that majority of the respondents were computer literate and frequently accessed the internet to retrieve relevant academic materials, and identified power outages, slow internet speeds and lack of computer terminals as some of the challenges faced by students. Adeyinka & Oyedeji (2020) study investigated impact of e-learning on student engagement and learning outcomes. The results showed significant improvements in student engagement, motivation and academic performance. Nikolopoulou (2022) investigated University students' opinions and preferences regarding face-to-face, online and hybrid modes of education, soon after their return to traditional face-to-face classes. The findings revealed major perceived disadvantage as demanding timetable; perceived benefits to include time and space flexibility and familiarity with digital technology; negative opinions regard technical problems and loss of practical classes.

Garrison, Cleveland-Innes & Fung (2021) meta-analysis synthesizes research on effective strategies for promoting student engagement in online courses, including instructional design principles, pedagogical approaches, technological tools, and support services. It provides evidence-based recommendations for educators and institutions seeking to enhance online engagement and student success. Means, Toyama, Murphy & Bakia (2013) meta-analysis provides evidence that online learning is as effective as face-to-face learning and that Blended learning models are more effective than online or face-to-face learning alone. It equally ascertained that students' satisfaction and engagement are higher in online learning environment.

Conclusion

This study empirically ascertained the extent of undergraduate students' agreement to online classes providing better understanding of course content; making it easier to pay attention to lectures; not being convenience and irregularity in attending online classes; not being easy to clear doubts during the class; not making peers and teachers miss social interaction; and does not make classes less engaging; greater agreement to students facing technical issues during online classes, students likely attending online classes more and sticking to the time table of traditional classes as compared to online classes. It has been used to establish students' autonomy in navigating digital learning environments, their perceived competence in using online tools and their sense of relatedness to peers and teachers.

Recommendations

- Tertiary institutions having gained valuable insights into the dynamics of online engagement among her students can leverage on it.
- Institutions can identify strategies for optimizing online learning environment to promote student success and satisfaction.
- Educators and institutions can tailor support services and training programs that would meet students' needs.
- Educators and institutions are left with no other choice than to accept the change for effective technological integration

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A Four-Tier Diagnostic Test to Determine Pre-Service Science Teacher's Misconception About Solution

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Abstract

Misconceptions are one of the most serious obstacles to the effective and efficient conduct of science education. Therefore, it is very important to determine misconceptions. In the study, a misconception diagnosis test was developed for the topic of solutions. The validity and reliability studies of the misconception diagnostic test developed by the researchers were carried out with 203 pre-service science teachers. The analyses indicate that the developed diagnostic test satisfies the validity and reliability criteria essential for identifying misconceptions within the group of pre-service science teachers concerning the topic of solution. The developed test consists of eight questions in four stages. The test showed a two-factor structure. The reliability coefficient of the test was calculated as KR-20, .704 for scientific knowledge and KR-20, .741 for misconceptions. Researchers believe that the conceptual misconception diagnosis test they have developed will serve as a guide for efforts to identify and eliminate existing misconceptions about solutions in prospective science teacher candidates. A four-stage misconception diagnostic test for the subject of solutions was not found in the literature. In this respect, the study is considered to be unique and powerful.

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Introduction

Science is a complex structure that includes many disciplines. One of these disciplines is chemistry. Chemical science is a science closely interacting with our daily life. Many products we use in our daily lives, many information, problems or problems we encounter include concepts related to chemistry science. The fact that these concepts related to chemical science are highly abstract makes it difficult for individuals to concretise these concepts in their own mental processes (Gilbert, 2006). The subject of solutions within the scope of chemistry is one of the subjects closely related to daily life. The first meeting of the concept of solution with students in the educational environment takes place in the 7th grade of primary education within the scope of science curriculum. The solution subject is one of the basic subjects of chemistry. The knowledge of the subject of solutions is the basis of many learnings that individuals will perform throughout their lives, in their daily lives and in education and training environments related to science. For this reason, learning the concepts related to this subject correctly and completely is important for future learning (Demirba et al., 2011).

Misconceptions are the biggest and most serious obstacle for all educational fields including science education. In order for deep and meaningful learning to occur in individuals, concepts must be learnt completely and correctly. Concepts that are not learnt correctly cause individuals to be unable to make sense of their learning in a scientific way and to establish correct relationships between scientific knowledge (Iwuanyanwu, 2019; Mataka & Taibu, 2020). For this reason, misconceptions are one of the issues that educators of science and other fields have paid serious attention to in recent years. Individuals' understanding of concepts is of great importance for science educators for the same reason. Information that is accepted as scientific knowledge by individuals but conflicting with scientific facts is referred to as a misconception (Allen, 2014; Eshach et al., 2018; Soeharto et al., 2019; Vosniadou, 2020). When reviewing the literature, numerous studies are found which showing that students have misconceptions about chemistry subjects (Abraham, et al., 1994; Camacho & Good, 1989; Ebenezer & Ericson, 1996; Garnett & Treagust, 1992; Pardo & Solaz-Patolez, 1995; Yasa & Kocak, 2022). Subjects containing abstract concepts are generally difficult to learn by students. The fact that the concepts contained in chemistry subjects are generally abstract concepts causes misconceptions in chemistry subjects. The fact that the academic language used in chemistry is far from everyday language and contains detailed calculations causes these subjects to be difficult to learn and contain misconceptions (Carter & Brickhouse, 1989; Üce & Ceylan, 2019; Veiga, Pereirave & Maskill, 1989). The subject of solutions is one of the subjects in which students have misconceptions (Blanco & Prieto, 1997; Demirbaş et al., 2011; Erdem et al., 2004; Friedler et al., 1985; Gabel & Samuel, 1987; Smith & Metz, 1996).

The main goal of this study was to create a measurement tool designed to identify misconceptions held by pre-service science teachers concerning the subject of solutions. In the study, a four-tier misconception diagnosis

test was used as a data collection tool. The data collection instrument was created by the researchers within the scope of the study. Four-tier misconception diagnostic test prepared for the subject of solutions was not found in the literature. In this respect, the study is an original and powerful study. The misconceptions determined by the test developed by the researchers can reveal at which point of the subject of solutions students have unscientific beliefs. In addition, the determination of misconceptions will guide the improvement studies to be carried out to correct these misconceptions.

Method

Research Design

This study, which purposes to develop an assessment tool to designate the misconceptions of pre-service science teachers about the subject of solutions, was modeled with quantitative research method. The study employed the survey method, a quantitative research approach. The survey design is a quantitative study carried out on the whole universe or a group formed from the universe in order to reach an opinion and judgment in general terms about a universe shaped by a large number of elements. In studies conducted with the survey design, the current status of the universe, trends or values of the universe can be revealed (Creswell, 2017; Karasar, 2005).

Study Group

The research includes a study group comprising 203 pre-service science teachers. The study group consisted of pre-service science teachers from each grade level continuing their undergraduate education in the science teaching department of a state university in Turkey. The study data were gathered in the spring semester of 2022-2023 academic year. The study group was selected through the convenient sampling method. Convenience sampling refers to the process of collecting data from a research population that the researcher can reach. Basically, it can be defined as determining and using a sample that the researcher can easily reach (Koerber & McMichael, 2008; Rahi, 2017). The graph showing the number distribution of pre-service science teachers according to grade level is presented in Figure 1.

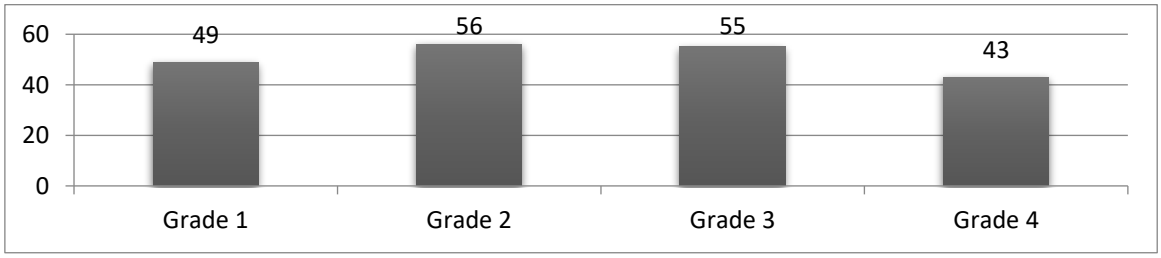

Figure 1. Pre-Service Science Teachers' Grade Levels

Data Collection Tool and Process

The "Solutions Four-Tier Misconception Diagnosis Test" used in the study was developed by the researchers. The developed solutions four-tier misconception diagnostic test consists of eight questions. During the test development process, the researchers benefited from literature review on misconceptions and instructor observations. During the question preparation process, firstly, a comprehensive literature study on the subject was conducted and misconceptions in the literature on solutions were determined. Then, a pool of items was formed by blending the misconceptions identified by the instructors in the course and laboratory applications and the misconceptions in the literature. The statements in the item pool were analysed by the researchers. As a result of the examination of the item pool, eight questions that harbor possible misconceptions were decided upon. The eight questions were formed as multiple-choice and turned into a four-tier diagnostic test with the addition of reason and confidence steps. The developed draft test was sent to three field experts and expert opinions were obtained. Two of the experts whose opinions were requested were science educators and one of them was a chemistry educator, and they were field experts who had studies on misconceptions. The test took its final form by making arrangements with feedback from the expert opinions.

Data Analysis

Four-tier misconception diagnostic tests do not only identify misconceptions. These tests can also detect scientific knowledge, false negatives, false positives and lack of knowledge. During the calculations, correct answers are coded as “1” and incorrect answers as “0” for all stages. In confidence levels, statements expressing confidence are coded as “1” and statements expressing uncertainty are coded as “0”. The coding and findings of the four-tier misconception diagnostic tests are presented in Table 1.

Table 1. Coding of Four-Tier Misconception Diagnostic Tests and Possible Detections

First Tier	Second Tier	Third Tier	Fourth Tier	Coding	Final Decision
True	Sure	True	Sure	1-1-1-1	Scientific Knowledge
True	Sure	False	Sure	1-1-0-1	False Positive
False	Sure	True	Sure	0-1-1-1	False Negative
False	Sure	False	Sure	0-1-0-1	Misconception
True	Sure	True	Not Sure	1-1-1-0	LK 1
True	Not Sure	True	Sure	1-0-1-1	LK 2
True	Not Sure	True	Not Sure	1-0-1-0	LK 3
True	Sure	False	Not Sure	1-1-0-0	LK 4
True	Not Sure	False	Sure	1-0-0-1	LK 5
True	Not Sure	False	Not Sure	1-0-0-0	LK 6

False	Sure	True	Not Sure	0-1-1-0	LK 7
False	Not Sure	True	Sure	0-0-1-1	LK 8
False	Not Sure	True	Not Sure	0-0-1-0	LK 9
False	Sure	False	Not Sure	0-1-0-0	LK 10
False	Not Sure	False	Sure	0-0-0-1	LK 11
False	Not Sure	False	Not Sure	1-0-0-0	LK 12

*LK; Lack of Knowledge

The four-tier misconception diagnostic tests can detect a total of 16 different situations, including 12 different lack of knowledge statements. When interpreting the answers given by the participants to the test; if the person answered the first and third steps correctly and is sure of his/her answers, it is expressed as scientific knowledge; if he/she answered the first and third steps incorrectly and is sure of his/her answers, it is expressed as misconception. If the participant answered correctly in the first stage and incorrectly in the third stage and is sure of his/her answers, it is defined as false positive, and if the participant answered incorrectly in the first stage and correctly in the third stage, it is defined as false negative. When Table 1 is examined, it is noteworthy that there is uncertainty in at least one of the confidence steps while determining the types of lack of knowledge. If the learner is not sure of his/her answer (regardless of whether the answer is correct or incorrect), this is interpreted as a lack of knowledge. The finalized Solutions Four-tier Misconception Diagnosis Test was checked in terms of language, comprehensibility and fluency by having a pre-service science teacher from each grade level read the test after the adjustments made in line with the expert opinions.

Before the main application, a pilot study was conducted by applying the test to a group of pre-service science teachers who were not included in the study group. A group of forty eight pre-service teachers from each grade level was selected for the pilot study. The reliability coefficient was calculated after the pilot study. Both reliability coefficients calculated for the four-stage misconception diagnostic tests (KR-20 calculated for misconception scores (.706) and KR-20 calculated for scientific knowledge scores (.689) were within the appropriate range. After the pilot study, 203 pre-service science teachers were recruited for the main application. The validity and reliability studies of the test were carried out with the data obtained.

Results

Test Reliability Analysis

In the process of reliability analysis of four-tier misconception diagnostic tests, two different reliability coefficients are calculated. These coefficients: the reliability coefficient computed for misconception scores and the reliability coefficient computed for scientific knowledge scores within the same sample.

First Type Reliability: Scientific Knowledge Reliability Coefficient

The first reliability coefficient of the solutions misconception diagnostic test is computed based on the scientific knowledge score derived from instances where respondents answered the test questions correctly and expressed confidence in their responses. In fact, it is the reliability coefficient calculated over the score obtained by coding the participant responses as 1-1-1-1. The first reliability coefficient of the solutions misconception diagnostic test was determined as .704 through KR-20 analysis.

Second Type Reliability: Misconception Reliability Coefficient

The second type reliability coefficient of the solutions misconception diagnostic test is computed based on the misconception score derived from instances where respondents answered the test questions incorrectly but were confident in their responses. When calculating this reliability coefficient, the score obtained by coding the participant responses as 0-1-0-1 is taken as basis. The second type reliability coefficient of the solutions misconception diagnostic test was determined as .741 through KR-20 analysis.

When the literature is reviewed, it is seen that the reliability coefficient calculated at .05 and above in tests where the number of items is less than 15 is found to be satisfactory. Both calculated values indicate that the test is a reliable measurement tool (KR-20 > 0.7) (Mc Alpine, 2002; Vegada *et al.,* 2014).

Validity Analysis of the Test

The validity of the four-tier misconception diagnostic tests is assessed through data obtained using four distinct methods (Taban & Kiray, 2021).

Validity 1: Expert Opinion

In the process of preparing the questions and creating the item pool, expert opinions were obtained from two science educators for the organization of the open-ended questions asked to the pre-service teachers. After the question preparation and test development phase was completed, the pilot test was shared with two science education experts and one chemistry education expert working as faculty members in different universities. Expert opinions were received and necessary corrections were made.

Validity 2: False Positive and False Negative

One of the conditions for ensuring validity in the four-tier diagnostic tests is the calculation of the percentages of positive false and negative false total scores below 10% (Hestenes & Halloun, 1995). In the analyses conducted using data collected from pre-service teachers as part of the study, the average false positives were computed as 9.79%, and the average false negatives were calculated as 3.69%. Both figures fall below the 10% threshold.

Validity 3: Factor Analysis

Factor analysis was conducted to assess the construct validity of the test designed to identify misconceptions among pre-service science teachers regarding the topic of solutions. In this step, Exploratory Factor Analysis was applied to the developed test. The KMO value obtained as a result of the analyses shows that the developed test is suitable for factor analysis (KMO; .757). The obtained KMO value shows that the sample size is sufficient. When the literature is examined, it is seen that the KMO value is considered appropriate for samples of this size when it is calculated as 0.7 and above (Guttman, 1954; Kaiser, 1970). Bartlett's Test of Sphericity, another value for factor analysis, was found to be significant ($p<.05$). This value supports that the data are suitable for factor analysis (Shrestha, 2021). With the exploratory factor analysis, the test showed two sub-dimensional structures. The eigenvalue criterion was taken as a basis in determining the sub-dimensions, i.e. factors (Pallant, 2010; Verma, 2013). Two factors with an eigenvalue value of 1 and above were determined as sub-dimensions. The analysis shows that these two factors explain 54.55% of the total variance.

Based on the findings of the exploratory factor analysis, the developed test has two sub-dimensional structures. The first sub-dimension is the solubility sub-dimension including questions 1, 3, 6 and 8; the second sub-dimension is the type of solvent and solute sub-dimension including questions 2, 4, 5 and 7. The findings from the exploratory factor analysis are outlined in Table 2.

Table 2. Results of Exploratory Factor Analysis

Sub Dimensions Items	**Solubility**	**Type of Solvent and Solute**
1	.700	
3	.596	
6	.550	
8	.688	
2		.835
4		.760
5		.485
7		.783

When Table 2 is examined, it is seen that factor 1 is labeled with the title of solubility. The items within the scope of factor 1 are items 1, 3, 6 and 8. These items have a correlation of 0.70, 0.59, 0.55 and 0.68 with factor 1, respectively. Factor 2 is named as the type of solvent and solute. The items within the scope of this factor are items 2, 4, 5, and 7. The correlations of these items with factor 2 are 0.83, 0.76, 0.48 and 0.78.

Validity 4: Correlation Between Science Teacher Candidates' Confidence Scores and Correct Answer Scores

In the research, three distinct correlation coefficients were computed to investigate the relationship between the scores of correct answers and the confidence levels of pre-service teachers. These;

1. Correlation coefficient for the first tier and second tier (associated with the first confidence score).
2. Correlation coefficient for the third tier and fourth tier (associated with second confidence score)
3. Correlation coefficient between the first and third tiers and the second and fourth tiers (both confidence score). The results derived from the analysis are showcased in Table 3.

Table 3. Correlation Coefficient of Solutions Misconception Diagnostic Test

Tier Scores	**Pearson Correlation**	**p**
Confidence Score (First)	.293	.000
Second Confidence Score (Second)	.274	.000
Confidence Score (Both)	.331	.000

The first confidence score was calculated as .293. This coefficient score indicates that there is a meaningful positive relationship between the answers given by the pre-service teachers to the first and second steps. The second confidence score was calculated as .274. This coefficient indicates that there is a meaningful positive correlation between the pre-service teachers' responses to the third and fourth step. The final correlation coefficient pertains to the correlation calculated based on the responses provided by pre-service teachers to the first and third steps with the second and fourth steps. This value was calculated as .331 and it indicates that there is a meaningful positive relationship between both confidence scores of pre-service teachers. Taban and Kıray (2021) noted that given the challenging nature of misconception tests, there should be a meaningful positive relationship between the mentioned steps, even if it is weak. Considering this criterion, it is evident that the validity criterion is satisfied. A sample question of the developed test is presented in Figure 2.

6.2. When a certain amount of a saturated solution is used, how does the concentration of the remaining solution change?
A) The concentration decreases
B) The concentration increases
C) The concentration does not change

6.2. Are you sure about your answer above?
A) Absolutely sure
B) I am sure
C) Not Sure
D) Absolutely Not Sure

6.3. Which of the following is your reason for selecting the above option?
A) If the amount of solvent decreases, the concentration decreases.
B) If the amount of solvent decreases and the solute precipitates, the concentration decreases.
C) Since the amount of solute per unit volume decreases, the concentration decreases.
D) Since the amount of solvent decreases, the amount of solute per unit volume increases, and the concentration increases.
E) Since both the solvent and the solute decrease in the same proportion, the concentration does not change.
F) Since the amount of solvent decreases while the amount of solute remains the same, the concentration does not change.
G) Other (Please specify if you have another reason)

6.4. Are you sure about your answer above?
A) Absolutely sure
B) I am sure
C) Not Sure
D) Absolutely Not Sure

Figure 2. Example Question

Misconceptions, Scientific Knowledge, False Positive and False Negative Rates of Pre-Service Science Teachers About the Subject of Solutions

The percentages of pre-service science teachers in the categories of scientific knowledge, misconception, false positive, false negative and lack of knowledge about the subject of solutions are presented in Table 4 on the basis of question and factor.

Table 4. Classification and Percentage Ratios of Pre-Srvice Teachers' Answers by Question and Factor

	Factor 1; Solubility					**Factor 2; Type of Solvent and Solute**				
Test Items (%)	1	3	6	8	X	2	4	5	7	X
Scientific Knowledge	40.88	61.08	50.24	54.18	51.60	53.20	37.93	32.01	29.55	38.17
False Positive	9.85	6.40	15.27	7.38	9.72	4.92	13.30	0.98	20.19	9.85
False negative	2.46	0.49	0.98	20.19	6.03	0	4.43	0.98	0	1.35
Misconcep-tion	14.28	16.74	11.82	13.30	14.03	2.46	6.89	13.30	7.88	7.63
Lack of Knowledge	32.53	15.29	21.69	4,95	18.61	39.42	62.55	52,73	42.38	49.27

When Table 4 is analyzed, it is observed that the question with the highest percentage of scientific knowledge (61.08%) is the third question and the question with the lowest percentage of scientific knowledge (29.55%) is the seventh question. When the false positive percentages of the pre-service science teachers were analyzed, it was seen that the question with the highest percentage of false reasoned truths was the seventh question (20.19%) and the question with the lowest percentage of false reasoned truths was the fifth question (0.98%). When the percentage of false negative, which we call as errors with correct reasons, is analyzed, it is seen that the highest percentage of false negative is in the eighth question, while the lowest percentage of false negative is in the second (0%) and seventh (0%) questions. While answering the eighth question, 20.19% of the pre-service teachers made the right choice at the reason step and the wrong choice at the content step. Another finding obtained when Table 3 is analyzed is the misconceptions of pre-service teachers about the subject of solutions. When the table is analyzed, it is seen that the question with the highest rate of misconceptions is the third question (16.74%) and the question with the least misconceptions is the second question (2.46%). Another finding obtained as a result of the analysis is the percentage of lack of knowledge of the pre-service science teachers. According to the results of the analysis, 62.55% of the pre-service science teachers stated that they were not sure about at least one of the confidence step answers while answering the fourth question. The question in which pre-service science teachers had the least knowledge deficiency was the eighth question (4.95%).

Discussion and Conclusion

The aim of this study is to create a valid and reliable measurement instrument capable of identifying misconceptions among pre-service science teachers regarding solutions. In the course of the research, a four-tier misconception diagnosis test was specifically developed for this purpose. The developed misconception diagnosis test has two sub-dimensions as "solubility" and "type of solvent and solute". These two sub-dimensions of the misconception diagnostic test were reached by exploratory factor analysis. According to the findings of the exploratory factor analysis, the first, third, sixth and eighth items are the questions prepared within the scope of the first sub-dimension, solubility factor. The second, fourth, fifth and seventh questions belong to the second factor, solvent and solute type dimension. The findings obtained from the validity and reliability studies show that the diagnostic test developed has standards that can be used to identify misconceptions about the subject of solutions. For the reliability analysis of the test, KR-20 reliability coefficient was calculated on the basis of misconception and scientific knowledge scores and this coefficient was above .70 in both categories. Validity analyses were conducted through four steps, and the outcomes of all the analyses indicate that the test is a valid and reliable measurement tool.

Upon reviewing the misconception analyses, it is evident that pre-service science teachers harbor significant misconceptions (10% and above) related to the content of the first, third, sixth, eighth, and fifth questions. Similarly, when the lack of knowledge analyses are examined, it is seen that pre-service science teachers have notable (10% and above) lack of knowledge in all questions except the eighth question. According to the results of the analyses, over half of the pre-service teachers have lack of knowledge for the fourth and fifth question contents.

When the literature is examined, studies focusing on the determination of misconceptions about the subject of solutions are found. Although different methods and techniques were used to identify misconceptions in the studies, there was no study using a four-tier misconception diagnostic test. For example, Kalın and Arıkıl (2010) aimed to determine the misconceptions of university students in different departments about the subject of solutions by using the interview technique in addition to the open-ended questions they prepared in their study. Demirbaş et al. (2011) used open-ended questions to determine the misconceptions of pre-service science teachers about the subject of solutions. In addition to open-ended questions, the researchers also asked for the reason for the answer. Koray et al. (2003) developed a misconception test to determine high school students' misconceptions about solubility. The developed test consists of two parts: definition of the concept and application question. Bulut et al. (2021) determined the misconceptions of pre-service chemistry teachers about solutions and solubility through concept maps. Liu and Lesniak (2006) aimed to reveal high school students' misconceptions about the concept of dissolution and used semi-structured interview questions in the data collection process. Krause and Isaacs-Sodeye (2013) used a worksheet to reveal the misconceptions of university students from different departments about the concepts of solutions, solubility and saturation.

When the literature is examined, it is seen that misconceptions about solutions are tried to be determined by using different methods and techniques. However, there is no study in which four-tier diagnostic test was used to determine misconceptions about solutions. Four-tier diagnostic tests are very important in terms of presenting the reason for the individual's answer to the question about the concept. Misconceptions are serious problems that can cause wrong learning by affecting lifelong learning processes. In this context, it is very important to identify them. The test created in the context of this study was designed to identify the misconceptions held by pre-service science teachers regarding solutions.

Recommendations

It is considered that determining the misconceptions of pre-service teachers by using the developed test is important in terms of determining the focus in curriculum development studies. It is also thought that the test formulated as part of the study can be used as a pretest-posttest within the scope of an appropriate application plan by designing an experimental study and the elimination of misconceptions can be controlled.

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Post-traumatic Growth and Reconstruction of Values in The Shack Film

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Abstract

Trauma is used to name all kinds of events that leave deep scars in the mental and physical being of a person. It is a deep emotional and psychological wound experienced by the individual after an unexpected and shocking event or in the face of a situation involving physical and psychological threat. Such profound events can lead to the decline or complete breakdown of personal beliefs, values and social bonds. Cinema is one of the powerful artistic tools that can read individual and social changes. Thanks to its audiovisual effects, cinema offers the opportunity to analyze the mental state of the characters. The Shack, based on the novel by Paul Young, deals with the effects of the trauma of loss and how the individual emerges from this process and how values are rebuilt with spiritual guidance centering on the experiences of a father. The aim of the study is to reveal how the protagonist Mack's deep spiritual journey after the loss of his daughter leads him to re-establish family ties and core values such as love, justice, faith and forgiveness. This study is limited to the film The Shack (2017) and will be analyzed with the semiotics method.

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Introduction

The word trauma is a term first used in medicine to describe physical injuries involving bone or tissue damage. In psychological and emotional contexts, it refers to a situation in which an individual's mental processes such as perception, feeling, thinking, memory or imagination are restricted or unable to function for a certain period or in the long term (Puppert, 2011). It is an unexpected event or situation that leads to serious physical and psychological consequences. Man-made traumas such as sexual assaults, wars, torture and violence or traumas resulting from natural disasters such as earthquakes, floods and fires leave permanent deep scars on the body, mind and psyche regarding the perception the world. Especially when social position, professional status and belonging are threatened, the effect of these scars remains. Powerlessness, resignation, leaving oneself to the mercy of others, lack of trust (Fischer & Reidesser, 1998), pain, sleep disturbance, depression, anxiety, hypersensitivity, shock, obsession are some of the conditions caused by trauma. With traumatic events, values become worthless and beliefs weaken (Sztompka, 2000).

Considering that there is a belief under every value (Aydın, 2013), exposure to trauma destroys the knowledge of what is right and wrong, individual attitudes and behaviours criteria, and generalized moral rules (Köse & Dağyar, 2021). However, it has also been revealed that not only negative but also positive changes can be experienced after traumatic events, and that the person becomes stronger than before. The situation called post-traumatic growth is the idea that great good can come from great pain, the positive change experience that emerges as a result of struggling with the difficult life crisis after trauma (Tedeschi & Calhoun, 2004). How an individual can grow and change after a traumatic experience was organized into three main categories: changes in self-perception, such as becoming a better person, feeling strong and self-assured; becoming more considerate of other people; and changes in philosophy of life (spiritual change, rich spiritual life). This approach was categorized into five dimensions: ‘personal power,’ ‘new possibilities,’ ‘relationships with others,’ ‘appreciation of life’ and ‘spiritual change’ (Tedeschi & Calhoun, 1996).

In literature and religious teachings, it is frequently emphasized that human suffering brings one closer to knowledge, truth and God (Ezerbolat & Özpolat, 2016). As a branch of art, there are studies that address the process of reconstruction of post-traumatic values in cinema, which is the subject of the study, and show the change of the trauma process in self-discovery, personal development and relationships with others. The study titled ‘A Review of the Film "Yuli" in Terms of Trauma, Growth and Creativity’ tells the real life story of the famous dancer Carlos Acosta. His life is shaped by difficulties and traumatic experiences, especially during his childhood. The film shows Acosta's process of overcoming these difficulties and how he grows and matures in this process. Dance has been both an escape and a means of self-discovery for the character. In addition, there are also studies on healing from trauma and bereavement.

The study titled "An Analysis of Krzysztof Kieslowski's Three Colors: An Analysis of Krzysztof Kieslowski's Three Colors: Blue" within the framework of the concepts of 'Trauma', 'Mourning' and 'Healing'" focuses on the story of Julie, the female character of the film, who loses her husband and daughter in a car accident, and the story of her recovery from this trauma. In a study by Becerikli and Boz (2019), the film 'Butterflies' (2018) seeks to explain concepts such as trauma, mourning and recovery through the experiences of adult characters. In addition, "The Pursuit of Happyness" (2006) deals with the efforts of a father struggling with financial difficulties and homelessness trying to build a better life for his son and his personal growth in this process. 'The Impossible' (2012) tells the true story of a family that survived the 2004 tsunami disaster. The film reveals how, in the aftermath of a traumatic disaster, family members strengthen their commitment to each other and learn to re-appreciate the value of life. These films and film studies reveal the effects of traumatic experiences on the spiritual and personal development of individuals.

A study looked at how Christian-based films have the potential to be applied as a spiritual discipline for spiritual growth. These films include The Shack (Booth, 2023). In this study, the movie The Shack, based on William P. Young's eponymous novel, will be analyzed in the context of post-traumatic growth, forgiveness, justice, and the reconstruction of faith values. The main reasons behind the choice of this film are that its story clearly reflects the individual and spiritual transformation, emphasizes the construction process of social values, offers rich content for semiotic analysis with its symbolic narrative, and emphasizes that trauma does not only have a negative aspect but also offers opportunities for learning and growth. The study is limited to the film The Shack and the film has been analysed with the semiotics method.

Trauma Phenomenon and Post-traumatic Growth

The concept of trauma is used to name all kinds of events that shake and injure the mental and physical being of the individual in many different ways. Turkish Language Association (TDK) defines the term trauma as a concussion, a local wound that disrupts the structure and form of a tissue or organ and occurs as a result of an external mechanical reaction, and as an disturbance (TDK, 2024). A severe event that cannot be integrated and assimilated is called a wound that is difficult to cope with according to the person's capacity to recover and handle (Bilgin, 2003). Traumatic events are long-lasting experiences that occur in a person in the face of a situation involving physical and psychological threat. Therefore, traumatic events that occur at a certain time deeply affect the individual physically and psychologically. The deep scars engraved on the psyche or body of the individual affect entirely his/her identity, thoughts and lifestyle and shape his/her whole life. (Satır, 2022). During the 19th century, 'trauma' meant a severe tear on the surface of the skin, an open wound and did not carry any psychological connotation (Jones & Wessly, 2007). Trauma has been described as a short-term,

reversible situation under the responsibility of the subject. The person with mental disorders either has a problem regarding his/her personality or is suffering from a biologically-induced disorder; therefore, in both cases, the cause of the problem is the person himself/herself (Micale, 1989). Subsequently, emphasis has shifted towards placing more value on the individual's experience. The concept of trauma, which was originally favored for physical injuries, has been suggested to involve psychological traumas through studies on 'hysteria'. Sigmund Freud, who was inspired by the French neurologist Jean-Martin Charcot's hysteria studies and focused on the causes of hysteria, stated in his work Studies on Hysteria (1895), published jointly with Joseph Breuer, that the disorder in question was caused by traumatic cases such as sexual harassment in the past (Micale 2001; Micale, 1989). Thereafter, he altered his opinion that the neurotic symptoms of hysteria were not caused by traumatic memories, but by repressed sexual desires. In other words, Freud's theory of trauma includes the suppression of the individual's desires. As a result, studies have defined trauma as a psychological state.

Trauma can be observed to be man-made and induced by natural causes. In addition to traumas caused by natural disasters such as earthquakes, floods and fires, man-made traumas such as war, torture, violence and sexual assaults leave deep scarring on an individual. Trauma is heavily shaped by the twentieth century and the war experiences it brought along with it (Aygan, 2024). Freud studied the effects of traumatic experiences on individuals after the First World War and analyzed recurring dreams after war or accidents, which terrified the patient each time again. According to Freud, these dreams are related to the fact that the traumatic event affects the individual deeply and the person is stuck in this trauma (Freud, 2012). Trauma, according to Freud's definition, turns into a phenomenon that overturns the individual's defense mechanisms and transcends the shield that protects the individual against the outside world that captures him/her permanently (Aygan, 2024). Since traumatic events are processed very differently from normal information processing, they are recalled over and over again through nightmares and instant flashbacks. The mental disorders experienced by soldiers who did not have any previous disorders such as decreased reactions after the war, loss of interest in the things they previously enjoyed, remembrance of wartime, and difficulty in fulfilling daily tasks (Özen, 2017) attracted the attention of psychiatrists, and these disorders were diagnosed as traumatic neurosis. In this respect, individuals are stated to react differently to the trauma experience such as post-traumatic stress disorder, psychological resilience, and post-traumatic growth (Erten & Kocakaya, 2020). In this regard, it is emphasized that the trauma experience operates differently from person to person and that individuals show different psychological reactions. While individuals may experience emotional and physical negative experiences after trauma, some people show resilience against difficulties such as spiritual change and appreciation of life after traumatic experience.

Post-traumatic growth has focused on the positive changes and achievements as a result of coping with trauma. Indeed, 'The Long Defeat: Cultural Trauma, Memory and Identity in Japan', which examines the impact of traumatic events on shaping social structures and individual transformations, shows that Japan's historical wounds have shaped its national identity. It suggests that the traumatic past has a pedagogical function in the development of children in Japan (Hashimoto, 2015: 83). Psychological resilience and post-traumatic growth in disaster-exposed organisations: overview of the literature suggests that post-traumatic growth among rescue personnel is common at both personal and professional levels. This growth contributed to a greater appreciation of life and relationships, increased self-esteem and a better understanding of their work.

Experiences of coping with traumatic events strengthen employees' sense of commitment to society and help them value life more (Brooks et al., 2018). According to Janoff and Bulman (2004), through genuine support from others, many trauma victims are able to rebuild their inner world. In this process, a stronger psychological resilience, the ability to establish deep relationships, strengthening of family and community ties, and significant changes in their worldviews and perceptions of values are observed. According to the study of Dursun and Söylemez (2020), this restructuring process can lead the individual to a form of wisdom and make him/her more resilient against future challenges. In short, traumatic events, along with their negative aspects, also provide a function of making sense out of the pain experienced and reconstructing values and understanding of the world.

Making sense of traumatic events brings a sense of relief to a certain extent. In this case, values provide people a way of assessing the situations they encounter, and people acquire meaning through them by establishing a relationship with the emotions such as satisfaction, dissatisfaction, pleasure, sorrow that the situations arouse in them. For example, by developing a stance in the face of a painful event, a person has the potential to turn this situation in his/her favor and create a success story out of it. The key element here is that the person changes himself/herself, not the event (Erten & Kocakaya, 2020). In short, the values of the person reveal a meaning in the situations encountered. In this framework, individual's understanding affects his/her resilience against many adversities. Positive changes in interpersonal relationships, changes in self-perception, realization of the value of life, realization of the existence of alternative options and changes in the belief system are among the dimensions of post-traumatic growth (Tedeschi & Calhoun, 1996) and also show the results of coping with difficulties.

Trauma and Cinema

The traumatic events experienced during the First and Second World Wars were reflected in literary works such as poetry, novels and plays. Trauma has become an interdisciplinary phenomenon by opening up to disciplines

such as history, art, cultural studies and literature, especially after the official definition of trauma made by the American Psychiatric Association in 1980 (Aygan, 2024). The manifestations of trauma, which have become an integral part of social life due to the disasters experienced in the twentieth and twenty-first centuries, have been revealed through social structures such as religion, aesthetics and mass media. The aesthetic dimension plays an important role in the formation and intergenerational transmission of traumatic narratives; traumatic events gain functionality by being transformed into narrative through certain aesthetic forms (Alexander, 2012). Art forms such as movies, paintings and photographs have a critical importance in making trauma visible (Satır, 2022). It can create different indicators with its visual and auditory features, moving images, space, scenario, psychological and sociological factors, furniture design, etc (Üner & Erdoğan, 2021). In this way, cinema has a special importance among storytelling techniques.

Cinema creates emotional and mental reactions through the plot it conveys. It is a guiding communication tool that has a strong impact at both individual and societal levels in the transmission of inter-cultural information in the transmission of cultural and social messages. Cinema is also a powerful educational tool which is not independent of value judgments, ideological tendencies and attitudes. A film production reflects the beliefs, values and structures in the society and in this respect it serves as a witness for the society. Therefore, cinematographic productions are in line with the prevailing conditions and changes in society (Ateş, 2020). Films are used as a powerful tool to understand and describe the mental states of the characters. In this sense, they are texts that can clearly observe the changes experienced by the characters (Becerikli & Boz, 2019).

The Shack (2017 film)

The Shack has been directed by Stuart Hazeldine and is based on the 2007 novel of the same name by William P. Young. Baraka is the story of a protagonist who, through tragedy, pain, grief, doubt, unforgiveness and guilt, struggles with his relationship with God, himself, his family, his life and his faith. The first twenty minutes of the film give an idea of the contribution of Mack's past and present traumas to his faith and his relationship with God. As the story unfolds on screen, the audience journeys with Mack on a journey of healing and forgiveness with the Triune God. A process of liberation through an intimate encounter with the Triune God, addressing his past, facing his fears and accepting his imperfections frees Mack from the layered weights of despair. In turn, after significant loss and grief, he is renewed to see a hopeful future for himself and his family (Booth, 2023, 44).

Mackenzie “Mack” Phillips suffered from physical and emotional abuse as a child by his drunken father, who also abused his mother. Mackenzie “Mack” Phillips lives a fulfilling life with his wife Nan and children Kate, Josh and Missy. However, this peaceful life is wreaked havoc when Missy disappears during a camping trip.

In the aftermath, police find Missy's torn dress and a trail of blood in an abandoned cabin in the woods and conclude that the little girl was the victim of a serial killer. One day, Mack unexpectedly receives a typewritten message inviting him to meet him at the cabin. The message is signed "Father", the name Mack's wife Nan and his missing daughter Missy used for God. Mack initially thought of the message as an opportunity to confront and punish his daughter's killer. So he sets out on his journey. Along the way, he narrowly avoids a collision with a truck. When he reaches the cabin, he finds it empty, but at that moment he encounters a mysterious figure. This figure invites him to their home.

The mysterious trio at the house gradually reveals their identities to Mack: The African woman is God (the Father), the Middle Eastern man is Jesus and the Asian woman is the Holy Spirit. In the process, God, now in the form of an old native American man, leads Mack to the cave where Missy's body is found. Together, they buried Missy's body in the garden. Mack also encounters the wisdom of God, who appeared in the form of a woman named Sophia, in another cave. In this cave, Mack's confrontation with himself, his faith and his suffering deepens. Later in the journey, Mack encounters his father, who has mistreated him in the past and whom he finds it difficult to forgive. His father apologizes to Mack and Mack forgives him. Mack also faces his guilt for killing his father in the past and realizes that Missy's death was not a punishment for killing his father. In the end, Mack is able to overcome his deep grief and regain his faith. He says goodbye to the trio and sets off to return to his family. But on his way, he collides with the truck he had met earlier and loses consciousness, waking up in the hospital. Mack's friend tells him that he crashed on the way and never actually made it to the cabin. Later, Mack shares his spiritual journey with his wife Nan, and the movie ends with Mack going back to church with his family.

Method

This study is limited to the film The Shack and is analyzed by semiotics method. The theological messages of the film and criticisms about the characters of God are not included in the study. The sign emerges from the correlation between the 'signifier' representing the formal entity and the 'signified' representing the mental entity. Sign is like the front and back of a piece of paper, or the combination of an auditory image and a concept' (Barthes, 1979). Signs are actions that refer to something other than themselves, i.e. signification structures (Fiske, 2003). A sign is a meaningful entirety of various elements such as language, gestures, signs, traffic symbols, professional pennants, advertising posters, fashion, architecture, literature, painting and music, which people create and use for the purpose of communication, and which is expressed through tools such as sound, writing, image and movement (Rifat, 1992). It can also be defined as an object that shows something other than itself.

Semiotics, which is a branch of science that studies languages, icons and symbols, enables the discovery of the meaning behind the meaning of a text or image, rather than the obvious, apparent meaning of such text or image (Demir, 2009). The image or text has hidden, implicit meaning besides the content that is easily captured and perceived at first glance. Therefore, a flow runs from the visible to the invisible, from subjectivity to objectivity, from the concrete to the abstract, from the known to the unknown (Karaman, 2017). Semiotics suggests a view other than what is perceived at first glance. The signifier can be regarded as the material, tangible existence of a sign. The signified corresponds to the layer of meaning that the sign creates in the mind of the individual who perceives it. The semiotics method endeavors to make sense of signs by examining them in a specific context (Satır, 2019).

According to Barthes (2014), the denotation refers to what the sign represents, while the connotation refers to how the sign is represented. It is frequently used in film studies and advertisement analyses. The signs that constitute the production and transmission of meaning in cinema are divided into two as denotation and connotation. The concept of denotation refers to what we perceive directly from the whole of the scenes we encounter while watching the film. On the other hand, connotation can be summarized as the effort to find a meaning behind the images that appear as denotation in the script and storyline of the film (Aydıngüler, 2023). Regardless of how the connotation covers the denotation, it does not absorb it (Barthes, 1979: 89). In cinema, the elements reflected on the screen are characterized as the denotation, while the thoughts and meanings that emerge in connection with this meaning are evaluated as signified. In this framework, the signs in the movie The Shack were analyzed according to the denotation/connotation analysis.

Various events, elements and symbols in the movie carry connotations beyond denotation. For example, the shack is not only a place of shelter but also symbolizes the protagonist's inner state. As a matter of fact, the depiction of The Shack as a cold snowy place and its depiction on a warm sunny day give insight into the state of the character. Likewise, the effect of the trauma experienced by the character is shown through elements such as birds and boats. The waterfall and water symbolize the character's inner purification on the level of connotation. The garden figure represents forgiveness and healing, and the characters of God represent guidance and help through different appearances. Therefore, the film elaborates on denotative and connotative meanings of the shack, waterfall, garden and God figures and explains each of them in terms of inner growth and transformation.

Results

Individual Collapse and The Shack

The film begins with Mack's childhood memories. His father, one of the elders of the church, appears to be a religious figure, but he secretly drinks alcohol and inflicts violence on his mother and Mack. One of Mack's most prominent childhood traumas occurred when he complained about his father to a priest. As a result of this complaint, his father physically abused Mack and forced him to repeat the text “Children, obey your parents in everything, for this pleases the Lord. Colossians 3:20”.

Figure 1. Mack's violence by his father

Mack, physically and emotionally scarred at the age of thirteen, poisoned his father's drink, causing his death. This concealed tragedy constitutes the root of the character's faith crisis. The phrase ‘The secrets we keep have a way of clawing their way to the surface’, which shapes the theme of the film, emphasises the inevitability of confronting traumas. Mack's experiences are concretely illustrated by his recurring dreams and memories. Mack's family life, unlike the traumas he experienced in his childhood, is built on love and happiness. Living a more peaceful life with his own family, Mack regularly attends church. However, Mack's religious beliefs are different from his wife's. She has a deeper relationship with God and addresses him as ‘Father’ when she prays. The relationship of their little daughter with God and her faith is considered as a feature that makes her special and different from their other children. While Mack admires his daughter's closeness to God, he continues to have gaps and questions in his own faith.

The biggest trauma in Mack's life was the event called ‘The Great Sadness’ in the film. While Mack was trying to save his son from a canoeing accident during a camping trip with his children, he realised that his little girl was missing when he returned. The searches led to the discovery of her daughter's dress and traces of blood in a shack in the woods. That event changed Mack's faith and the balance of his life. By focusing on the missing or deceased person, emotions are left in the void. An individual's life can lose its meaning without the person

who has died or who is gone. Following the shock, the processes of searching for the person, disorganization and despair, and then recovery come into play (Puppert, 2011). As a matter of fact, a similar situation is observed in the trauma experienced by the character as a result of the death of her daughter. The shack, after which the film The Shack is named, is one of its strong symbolic elements and represents a great pain for Mack, all the fears he had to face spiritually as well as his inner journey. The Shack is not only a physical space, but also has a strong symbolic meaning as a metaphor where Mack confronts his traumas, questions his relationship with God and comes to terms with his pain. In the first screening, the shack is an abandoned, dilapidated, dark, cold old place. This shows Mack's state after his loss.

Figure 2. The shack where Mack's daughter was killed

The fact that the shack is the place where Mack encounters God and experiences a spiritual transformation in the later stages of the film increases the symbolic importance of this place. As an abandoned, dilapidated structure, the shack reflects Mack's inner conflicts and emotional destruction. This place witnesses Mack's darkest times, both physically and spiritually. However, in the process, the shack becomes a symbol through which Mack purifies his thoughts, learns to forgive and achieves spiritual healing. As a matter of fact, in the film, the first place Mack goes to is depicted as a cold, snowy and tense environment, while the place where he encounters God is depicted as a warm, green and reassuring place. This contrast is a concrete reflection of the transformation Mack experiences in his inner world. In other words, The Shack is an indicator of both trauma and post-traumatic growth. Mack is shown as withdrawn with the disappearance of his daughter, his relationship with his children weakened, his faith in God shaken, his social ties weakened, in other words, he is portrayed as isolated. The disappearance of Mack's daughter, on whom he built himself and to whom he was attached, was the trauma that would rock the subject to the core (Özmen, 2017). In a sense, the traumatic event experienced caused a great destruction in Mack's life.

One of the turning points of the film is Mack's call to the shack with a note left in the mailbox and signed 'Father'. Hesitant at first, Mack decides to go to the shack after consulting his friend. This journey, and thus the traumatic loss, became an important turning point in the recognition of the self and its reconstruction (Becerikli & Boz, 2019). When he arrived at the hut, Mack tried to commit suicide; however, he abandoned this attempt with the appearance of a deer. In the film, there is a reference to the deer as the sacred animal of Artemis, the Goddess of the hunt. This Goddess appears to young people and animals at their most pivotal moments, helping them to prepare for their destiny (Ayan, 2021).

Figure 3. Encountering a deer during a suicide attempt

Spiritual Guidance and Reconstruction Process

Mack's recovery from trauma begins when God calls him on a spiritual journey. This process develops through interactions in which God appears in three different manifestations - God (the Father), Jesus Christ (the young man) and the Holy Spirit (the young woman). These divine figures know even the smallest details of Mack's life. The Father figure takes the form of an African woman who helped Mack when he was young, but over time he can appear in other forms such as a middle-aged man. The Holy Spirit takes the form of a young Asian girl and Jesus appears as a young Middle Eastern man. When Mack encounters these figures, he realizes that the shack has changed from its abandoned and dilapidated state to a cleaner and more beautiful home. This spatial transformation shows Mack's inner transformation as he is growing after the trauma.

Figure 4. The shack to which God calls Mack

God told Mack that he had missed him for a long time and had called him to heal the growing emotional wound between them. Mack confronted God and expressed his pain. “You’re the almighty God, right? You know everything. You’re everywhere, all at once. You have a limitless power. Yet, somehow, you let my little girl die when she needed you most.” Mack questioned why God allowed his daughter to die and expressed his anger at God for turning his back on those he loved. This questioning reveals the chaos inside Mack and the damage to his faith in God. God, on the other hand, repeatedly told Mack that He loved him, that He never left his daughter and that He always saw his pain. God explained to Mack that the pain blinded him, so he could not see God's love. Avoiding pain, which is one of the important components of life, also has a meaning, and avoiding pain is also considered as avoiding life (Frankl, 2013). With the example of the bird in the garden, he explained that living without being loved is like breaking a bird's wing and that pain achieves this. At this point, Mack is symbolized as a bird next to the shack; the pain prevented him from flying and wounded him spiritually. The shack becomes a place of healing to heal this wound and make Mack “fly” again. Mack's interaction with God initiated a process of rebuilding his lost values of love, compassion, forgiveness and justice. God figures guided Mack in his inner healing. Mack's faith in and love for God was damaged, especially due to the trauma caused by the loss of his daughter. This spiritual guidance helped him heal his emotional wounds and rebuild his faith. The ever-changing forms of God figures, such as an African woman and a middle-aged man, emphasize that God can exist anywhere and in anything. As a matter of fact, Mack's perception of a punitive God and the idea that God is not good has changed with the different God figures shown in the movie.

Symbolism of Journey, Waterfall and Water

Water becomes a recurring theme in the film as a symbol of Mack's inner journey and spiritual purification process. Especially the scene where he is alone on the boat reflects the moments when Mack is alone with his traumas and pain. This scene is presented as a visual representation of the dark thoughts in Mack's mind and his self-destructive tendencies. The initially clear sea water becomes murky as Mack's dark thoughts intensify. However, at this moment, a figure of God reminds Mack to let go of his thoughts, to focus on himself and everything will be alright. As Mack focuses on God and accepts his guidance, his negative thoughts are shown to clear as the sea becomes clearer. In the following minutes of the film, when Mack is completely free from his thoughts, it is symbolized through the scene of him running on the sea that he is now in control of his thoughts and that he has taken a step towards healing.

Figure 5. Negative thoughts sinking the boat

A scene in which Mack confronts Wisdom in a cave is the culmination of his profound questioning of God. In that scene, Mack questions God's justice, asking him to judge and punish the murderer who killed both his father and his daughter. However, Wisdom tells Mack that he must take God's place and send one of his two children to hell. Faced with this difficult choice, Mack decided to sacrifice himself and thus realized how difficult it is to judge God. This scene symbolizes Mack's deep questioning of the concepts of justice and mercy and his eventual conviction that God is neither evil nor guilty. After reaching this realization, the waterfall metaphor comes into play and a window opens through which Mack can see his daughter. The scene where he passes under the waterfall reinforces the use of water as a symbol of forgiveness and spiritual cleansing.

Figure 6. Soaking/purification under a waterfall

The waterfall, used as an important metaphor in the film, represents a story that is associated with Mack's daughter. According to the story Mack tells his daughter, the princess, the daughter of a tribal chief, learns that the only way to get rid of the diseases in her land is to sacrifice her own life, and in order to make this sacrifice, she jumps from the waterfall and sacrifices herself for her people. In this context, the waterfall represents both the princess's sacrifice and a symbol identified with Mack's missing daughter. The tears of a father whose daughter is missing are also deeply associated with this metaphor. The waterfall is a powerful image that symbolizes Mack's emotional loss and inner pain as well as his purging of this pain.

Figure 7. The waterfall described during the trip to the camp

In conclusion, water stands out as a central metaphor for Mack's inner journey and process of overcoming his traumas. While representing both the process of purification and forgiveness, water plays an important role in Mack's confrontation with God and finding his own inner peace. In a sense, water serves as a means of overcoming Mack's traumatic experiences, a means of spiritual cleansing and transformation.

The Garden Figure and Forgiveness

Mack's healing process is symbolically visualized in the film and embodied through the metaphor of the garden. The garden represents Mack's complex inner and mental world, where both untidy and uncultivated elements reflect his post-traumatic mental state. The clearing of the bad, the weeds in the garden with God symbolizes Mack's process of healing his inner turmoil and pain through confronting it with the help of God. This action depicts Mack's effort to clear the chaos in his mind and the traumatic scars of the past.

Figure 8. Mack's weeding of the garden

The constant change of colors and natural elements in the film is directly related to the transformation in Mack's inner world. The dark and cold atmosphere Mack is in symbolizes his deep pain, disbelief and anger towards God. However, as the film plays out, nature comes to life, the colors become brighter and the atmosphere becomes warmer, which is a manifestation of Mack's process of reconciliation with himself and God, learning to forgive and believe again. The process of forgiveness is an important turning point as part of Mack's journey to forgive and heal himself and his family. Mack's process of forgiving his daughter's murderer is an important turning point in the film, where the character experiences a deep spiritual transformation and overcomes his trauma. The representation of God in different forms, especially as a middle-aged man who takes the place of Mack's father, symbolizes Mack's confrontation with both his personal past and his emotional distance from God. The scene of forgiving his daughter's murderer embodies Mack's process of confronting trauma and coming to terms with it. The fact that Mack takes the killer in the guise of an insect and releases him by saying "I forgive you" shows that his anger and desire for revenge has been replaced by forgiveness.

Figure 9. Mack not killing the insect

Forgiveness is nourished by religion and values and plays an important role in personal development, spiritual well-being, the elimination of biases, the relief of feelings of hopelessness and pessimism, and the resolution of conflicts in society (Özan & Aybala, 2024). This scene underlines that forgiveness is not only forgiving another person, but also a part of the process of healing oneself. When Mack reaches his daughter's body, he buries her in the prepared garden with the God figures. Their actions during the process of burying his daughter symbolically means burying Mack's traumatic loss in the ground and making a new beginning. The revival of nature as a result of the Holy Spirit pouring Mack's tears into the grave symbolizes Mack's spiritual purification and healing of the trauma. This scene also represents Mack's spiritual transformation along with the reawakening of nature.

Figure 10. His daughter's grave

The arrangement of the garden shows that Mack's inner turmoil and emotional disarray is over and that he has found peace and balance. While the garden in the film is a symbol of disorder and pain in Mack's mind, the

arrangement and revival of this garden with the God figures indicates that Mack has found his inner order and overcome post-traumatic destruction.

Figure 11. Mack's organized garden in which he buried his daughter

The restoration of the notions of forgiveness and justice are central to Mack's post-traumatic healing process. Throughout the movie, Mack learns to forgive not only his daughter's killer, but also his own father and himself. This process also radically changed Mack's understanding of justice. In the film, God teaches Mack that justice is not limited to punishment, but is also linked to forgiveness, mercy and love.

Restoring Family Relationships

In the film, Mack's eventual reconnection to his family, friends and community emphasizes a more positive growth and development of the character. This growth and development after trauma can be characterized by a change in one's view of oneself (Tedeschi & Calhoun 1996). The process of repairing his relationship with his daughter Kate, in particular, symbolizes Mack's effort to reconstruct the broken family ties and love that had been disrupted by the trauma. Mack, who re-established his relationship with his family, also came out of the process of loneliness and isolation that he had exposed himself to due to the trauma. He started to reintegrate into society by participating in religious ceremonies and social activities. As a result of trauma, some people can make positive progress such as finding the meaning of life and personal empowerment (Shakespeare-Finch et al. 2003). Mack found the meaning of the values he questioned, such as justice, forgiveness and faith, and became personally empowered. By the end of the movie, he has strengthened his family ties and developed a deeper and more sincere faith in God. The story ends by showing him finding happiness again in the same place called “The Day of Great Sadness”.

Conclusion

The movie The Shack deals with post-traumatic destruction and the process of post-traumatic growth. Mack's spiritual transformation after the trauma was effective in regaining values such as forgiveness, justice, love and strengthening family ties. This process, in addition to the many negative aspects of the trauma, helped him overcome these destructive impacts and become stronger. In the movie, many symbols such as the shack, water, the waterfall, the garden, different God figures show in detail the protagonist's trauma and post-traumatic growth process, the spiritual change, the restoration of the values of forgiveness, justice and love. Especially God figures, which are one of the main themes of the movie, are important indicators of post-traumatic spiritual transformation and serve as a guide in the post-traumatic process of the protagonist. For Mack, who questions values such as justice and forgiveness, God figures teach these values by reconsidering them. After the traumatic experience, changes in the character's self-perception, changes in his relationships with others, his philosophy of life and spiritual changes are presented through signs in the movie. The symbolic representation of nature coincides with Mack's inner world and transformation. Elements such as Mack's journey serve as sign systems that support the main themes of the movie and enable the audience to make in-depth meanings. Water symbolism expresses thoughts and emotions, purification. Therefore, the impact of trauma on the individual and his/her subsequent change is shown through colors, locations and dialogues. The plot shows that values such as forgiveness, justice, faith and love can be weakened or even damaged in times of crisis, but with the right guidance and social support, these values can be rebuilt. The film particularly focuses on post-traumatic growth and spiritual change, emphasizing that the destructive effects of trauma on the individual can be overcome and that it is possible to rebuild values. It also emphasizes the importance of confronting traumatic events and the role of forgiveness in the process of overcoming the impact of trauma.

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