Science to Think, Math to Design, Sports to Live

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EĞİTİM YAYINEVİ GRUBU

İÇİNDEKİLER

EFFECTIVE APPLICATIONS AND APPROACHES OF SCIENCE EDUCATION FOR SPECIAL EDUCATION STUDENTS

Mehmet Polat[1]

Abstract

This study presents a systematic review of research in the field of science teaching for children with special educational needs and emphasises the critical importance of promoting equity and inclusion in this context in terms of providing a high quality science education. Science education stands out as a fundamental field that supports individuals to understand the natural world, develop critical thinking skills and participate in effective problem solving processes. However, science learning for individuals with disabilities poses unique challenges such as different learning needs, limited resources, and the application of effective teaching methods.

The main purpose of this review is to identify the patterns, trends and knowledge gaps of existing studies in the field by searching important literature sources such as Google Scholar, Scopus, ERIC, Web of Science, ProQuest and YÖK Thesis database; as well as to identify potential areas for future research. The ultimate goal is to contribute to a more inclusive and science-based society. In the screening process, based on the established criteria, initially 280 publications were analysed and 96 of them were selected. After a detailed full text review, 26 publications were included in the study.

Designed as a qualitative research, this study aimed to identify themes related to the research topic through in-depth examination and content analysis of the selected publications. The reviewed studies were categorised under four main headings based on the interventions and practices addressed. These categories provided a comprehensive understanding and comparison of the methods and strategies used. The studies evaluated the effectiveness of technological tools, pedagogical approaches and strategies for improving science learning outcomes of children with special educational needs. Findings point to the need to tailor pedagogical materials and strategies to the individual needs of each student.

The research emphasises the importance of using a variety of research methods to understand the dynamics of different educational settings. In addition, it was indicated that educational interventions should be individualised and more than one data collection tool should be used in order to effectively improve teaching practices. In conclusion, this review aims to contribute to the provision of more

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inclusive and productive learning experiences for all individuals with special educational needs.

Keywords: Science education, Special education, Inclusive education approaches, Educational technologies, Equal opportunities in education

Introductıon

Access to science education for individuals with disabilities is becoming an increasingly critical issue in contemporary education systems (Adu-Boateng & Goodnough, 2022). With scientific and technological advances taking a central role in the life of society, ensuring that every individual has basic knowledge and skills in these areas should be one of the main goals of education (Cumhur et al., 2021; Humm & Schrögel, 2020). In this context, ensuring that children with disabilities benefit equally from quality science education not only contributes to their individual learning processes, but also stands out as a vital necessity in terms of strengthening equality of opportunity and social inclusion in education (Magnusson & Walton, 2021). Science education is a field of learning that provides students with skills such as examining natural phenomena, developing critical thinking skills (Hyytinen et al., 2019; Syafaren et al., 2019), and active participation in problem-solving processes (Lee et al., 2016). Such gains are even more important for individuals with disabilities who face unique difficulties in learning processes. Individualised science education programmes structured to meet their needs in this process not only increase their academic achievement, but also support the development of life skills such as self-confidence and social adaptation (Apanasionok et al., 2020; Kizilaslan et al., 2021). Developing strategies for educators to maximise the potential of children with disabilities through science education not only supports the personal development of individuals, but also constitutes an important step towards ensuring social justice and inclusion in education. This process is of strategic importance not only for individuals but also for the overall progress of society.

Science teaching for children with disabilities is a complex process that needs to be addressed with a multidimensional approach (Kahn & Lewis, 2014). Educators should make a comprehensive assessment by taking into account the different learning needs of students (Apanasionok et al., 2019), access to appropriate resources and technologies (Bancroft, 2002), and the most effective teaching methods that support learning (Knight et al., 2020). In this framework, continuous co-operation and co-ordination between educators, researchers and policy makers is necessary to produce solutions for the science education needs of individuals with disabilities. This joint effort will enable the implementation of pedagogical innovations and the creation of more inclusive learning environments.

Considering the critical importance of science education in today's society and the unique challenges faced by individuals with disabilities, there is a great need to revisit existing approaches and deepen studies in this field in order to ensure the effective participation of this student group in science education. Such efforts aim not only to enable children with disabilities to acquire scientific knowledge and skills, but also to position them as active and conscious individuals in a science-based society. Thus, social justice and inclusion can be strengthened by building an education system that provides equal opportunities for all students. This process will also make an important contribution to laying the foundations for a more conscious and sustainable future.

The aim of this systematic review is to thoroughly examine, analyse and synthesise the existing literature in a specific research area using the Scopus database as a primary source of information. The study aims to evaluate the current state of the relevant field and to reveal critical elements that can guide future research by seeking answers to the following research questions:

1. What are the main findings and contributions of the selected studies on the research topic obtained from Google Scholar, Scopus, ERIC, Web of Science, ProQuest and YÖK Thesis databases?
2. What are the prominent structural patterns and trends in the literature and how do these findings shape the theoretical and practical knowledge of the field?
3. What are the important knowledge gaps or controversial points that need to be addressed in the existing literature?

This study aims to provide a holistic perspective on the selected research area and to evaluate the main trends and academic contributions in the field. In addition, by identifying knowledge gaps in the literature and key contradictions that need to be resolved, it aims to provide new research directions and suggestions for advancing the body of knowledge in this area. Thus, it is aimed to clarify the current position of the topic in the academic literature and to make strategic contributions to the production of scientific knowledge.

Science Education for Special Education Students

In recent years, the education of students with special needs has undergone a significant transformation with reforms at both the legislative and practical levels. In the past, especially before the civil rights movement, individuals with special needs were often educated in segregated settings or completely excluded from education (Pertile & Riberio Mori, 2021). This reflects the lack of initiatives to increase inclusion in education systems and society's limiting view of individuals with special needs. However, legal regulations such as the Individuals with Disabilities Education Act (IDEA) and the Education for All Handicapped Children Act (ESA) have created fundamental changes in the

education system and secured the rights of students with special needs. These regulations emphasised the right of individuals with special needs to a free and appropriate public education and made it mandatory for them to be educated in the least restrictive environment (Walker et al., 2023). Today, this legal framework has created a continuum to ensure the integration of students with special needs into different learning environments and offers a wide range of educational options from special classes to general education classes (Agrawal et al., 2019; Bongwong, 2019; Erickson & Davis, 2015; Legeza & Lyutikov, 2023; Quapp & Holschemacher, 2023).

Despite this, serious problems and obstacles persist in the education of students with special needs, especially in the field of science. Research shows that these students continue to perform poorly on standardised tests and are underrepresented in science (Anastasiou, 2024; Gilmour et al., 2019; Juergensen & Zangori, 2023; Kahn & Lewis, 2014; Meek, 2020; National Science Foundation, 2017; Thornton et al., 2015). Asghar et al. (2017) in their research This research examines the cognitive and pedagogical challenges faced by students with learning disabilities (LD) in science and STEM fields and analyses how these challenges affect their academic achievement. It was found that inadequacies in information processing and problem solving skills in inquiry and problem-based learning processes constitute significant barriers for these students. In this context, the study emphasises that teachers cannot adequately respond to the needs of students with learning disabilities in inclusive education environments and the need for standardised approaches in diagnosis and implementation processes. As a result, by proposing effective intervention strategies for cognitive processing problems in science education, an important framework for increasing the participation and success of students with learning disabilities in STEM fields is presented. Similarly, Devi and Ingole (2023) aimed to examine the barriers to access to science education for individuals with visual impairment, how these individuals perceive science concepts, society's perceptions of science and visual impairment, and pedagogical difficulties in science classrooms. As a result of a systematic review, four main themes emerged: perceptions of individuals with visual impairment, challenges faced by these individuals, challenges faced by teachers, and suggested strategies for inclusive science classrooms. The findings reveal that students with visual impairments are underrepresented in science classrooms and that the learning process is challenging for both students and teachers due to the dominance of visual norms in science education. Although the research has provided strategies to address the existing problems, it emphasises that there is insufficient awareness among students, teachers and policy makers about the feasibility of these solutions. Ediyanto, Wulandary, and Fatmawati (2020) aimed to examine the difficulties faced by students with autism spectrum

disorder (ASD) in learning science and effective teaching methods. Based on the understanding that all students, including those with special educational needs, should have equal access to science education processes, the study particularly focused on appropriate learning strategies for individuals with ASD. As a result of a systematic review of eleven peer-reviewed articles published in the ERIC database between 2010 and 2019, it was found that interactive materials (such as science textbooks, e-books and computer programmes) are highly effective in science learning for students with ASD. However, there were no studies that addressed the participation of students with ASD in activities such as laboratory applications, problem-based learning models and argumentation-based science inquiry. Although the findings of the study emphasise the importance of supportive tools and appropriate pedagogical models for individuals with ASD to realise their potential in science learning, laboratory studies and inquiry learning models should be adapted to these students.

Another important change observed in education systems on a global scale is that individuals with special needs are generally preferred to be integrated into general education classes rather than being educated in separate institutions or classes (Dalgaard et al., 2020; Lartec & Espique, 2012; Choriyeva Shavkatovna, 2023; Polat & Tutak, 2024a). This change not only strengthens the understanding of inclusive education, but also aims to increase the social and academic success of individuals with special needs. In this context, the concept of 'science for all' has gained importance as an approach to ensure the participation of more individuals, especially students with special needs, in science education (Adu-Boateng & Goodnough, 2022; Humm & Schrögel, 2020; Polat & Tutak, 2024b; Thornton et al., 2015).

However, there are significant challenges to achieve this goal. The fact that practitioners do not sufficiently adopt the concept of 'science for all' and do not have the skills to realise this understanding is among the main reasons why students with special needs are not successful enough in scientific education. This deficiency is not only limited to teachers' lack of knowledge and skills, but also includes the lack of pedagogical and technical support necessary for the integration of individuals with special needs into science classrooms (Woolfson, 2024).

In order to create more inclusive and effective science classrooms, it is clear that there needs to be stronger co-operation between special education teachers and science teachers. Research shows that the lack of coordination between teachers is one of the important barriers to inclusive education (Villanueva et al., 2012). This kind of collaboration can make it possible both to design educational environments suitable for the needs of individuals with special needs and to make teaching strategies more effective. For example, science

teachers, in collaboration with special education teachers, can implement differentiated teaching methods in their classrooms more successfully and meet the individual needs of students with special needs.

Science Education for Students with Special Needs

Teaching methods to meet the diverse needs of students with disabilities in science education are enriched with a range of customised strategies and practices. These approaches include flexible and effective solutions that allow for the individualisation of education. These include evidence-based methods such as differentiating teaching processes, encouraging peer-supported interactions, tailoring educational materials to suit needs, making use of digital technologies and applying universal design principles (UDL). In addition, error-free teaching techniques, time delay strategies, systematic and behavioural-based methods, inquiry-based teaching and multisensory learning approaches can be considered in this context. The main purpose of these methods is to create inclusive science classrooms by increasing the academic achievement, participation in learning processes and motivation of students with disabilities.

One of the most frequently preferred methods in the context of special education is the adaptation of the delivery of education according to the individual needs of students with disabilities. This method is usually supported by peer interactive strategies that strengthen cooperation and communication between students and make learning a social process. Another important dimension is making educational materials accessible and organising them to address the different ability levels of each student. Such adaptations aim to make education inclusive and enrich students' learning experiences equally (Parris et al., 2019; Rix et al., 2009; Russell et al., 2022). Such teaching approaches not only increase the effectiveness of science education, but also contribute to ensuring equal opportunities in education.

Traditional strategies that yield effective results in the education of students with disabilities include the use of mnemonic devices (Jurowski, 2015), adaptive texts (Alber-Morgan et al., 2015), the provision of concrete experiences (Karlsudd, 2020), and the use of hands-on materials (Alber-Morgan et al., 2015; White, 2022). These methods aim to increase the academic achievement of students with disabilities by facilitating the learning process. Especially in the context of science education, inquiry-based activities supported by structured instruction and teacher guidance stand out as an effective tool to increase students' understanding of scientific concepts and their motivation to learn. Spooner et al. (2017) stated that systematic instruction, a method based on behavioural foundations, is highly effective in teaching a range of academic and life skills, especially to students with severe disabilities. The systematic teaching approach places great emphasis on a clear and structured teaching plan

as well as individualised learning procedures. This method aims to improve the quality of learning outcomes by providing a customised, step-by-step teaching process in accordance with the individual needs of students.

Polat and Tutak (2024a) aimed to examine the effect of artificial intelligence-supported education applications in increasing the attention span and interest of individuals with autism spectrum disorder (ASD) towards science and mathematics lessons. In the study conducted with the participation of students studying in a private educational institution in Elazığ, artificial intelligence supported interactive applications named 'Journey to the Mysterious World of Living Things with Artificial Intelligence' and 'Magical Journey in the World of Cubes' were used. Participants' attention span and interest in the lessons were evaluated before and after the application, and the data were analysed with SPSS 21. The findings show that artificial intelligence-supported educational applications significantly increase both attention span and academic achievement of individuals with ASD. The study emphasises the importance of disseminating these innovative methods in the field of special education.

In the science learning process, cognitive conflict can be used as an effective tool to develop students' metacognitive awareness and help them understand the differences between their existing beliefs and new scientific knowledge (Vosniadou, 2019). This approach aims to guide students to recognise and resolve contradictions between old knowledge and new concepts rather than directly revealing that their intuitive or prior knowledge is erroneous. In this way, students can develop meaningful understandings by taking an active role in the learning process.

The application of multisensory approaches in science teaching can increase students' interest and engagement in scientific concepts by enabling them to use their sensory channels more effectively. These methods include the use of three-dimensional objects, colourful visuals, illustrations, sounds, smells and tactile materials (Bancroft, 2002). Such enriched teaching strategies can deepen students' scientific understanding by making the learning process more concrete and meaningful.

Digital technologies stand out as an important support tool that strengthens the participation of students with disabilities in academic learning processes (McKissick et al., 2018; Starcic & Bagon, 2014). Different digital applications can help overcome various learning disabilities such as distraction, difficulties in staying on task, and memory problems (Chang & Hwang, 2018; Tu & Hwang, 2018; Turan & Atila, 2021). In addition, digital technologies function as an effective tool to increase the academic achievement, motivation, and engagement of students with disabilities (Mallidis-Malessas et al., 2022). These tools play an important role in meeting individual learning needs by making the educational process more accessible and interactive.

Universal Design Principles (UDL) draws attention as an innovative teaching framework that supports the understanding of inclusive education (Meyer et al., 2014; King-Sears & Johnson, 2020; Phelan, 2018; Spencer, 2011). UDL sets as a fundamental goal to meet the different needs of all students, especially individuals with disabilities, in the design of educational environments and materials (Adu-Boateng & Goodnough, 2022).

This framework aims to make students' learning experiences more accessible and effective by integrating individual differences into learning processes. Traditional teaching approaches include methods that have contributed to the education of students with disabilities for many years, such as concrete experiences, hands-on materials, mnemonic tools and adaptive texts. These methods focus on responding to individual needs by placing the learning process in a structured and supportive framework. On the other hand, strategies such as inquiry teaching and cognitive conflict represent a shift towards student-centred learning experiences. These approaches aim to increase students' intellectual engagement and deepen their understanding of scientific concepts. Contemporary approaches to special education focus on accessibility, inclusion and integration of technology. In addition to the framework of universal design principles, digital technology applications and multi-sensory teaching methods are recognised as modern strategies that enrich learning processes and appeal to a wide range of students. These innovative approaches aim to create a learning environment that can maximise the individual potential of each student, based on the principles of equality and inclusion in education.

Materıal and Method

In this study, document analysis method was preferred in order to give direction to future research by examining the types of studies conducted in the field of science education for special education students and the relationships between these studies (Minner et al., 2010; Baran & Bilici, 2015). Document analysis covers the processes of researching, identifying, analysing and evaluating existing sources for a specific purpose (Karasar, 2005). This method was applied in three basic stages: determination of the source scanning method and selection criteria, conducting the scanning process and performing the analysis process (Karaçam, 2013; Baran & Bilici, 2015).

In the research process, the procedures carried out with the document analysis method were structured in detail. In the first stage, a comprehensive planning was made to select the literature and data suitable for the purposes of the research in the process of scanning the sources and determining the selection criteria. In the second stage, the sources suitable for the determined criteria were searched. In this process, both national and international studies were accessed and appropriate sources were classified. In the last stage, the

analysis process, the selected sources were systematically examined and the findings obtained by determining the relationships between these studies were interpreted.

In addition to providing a comprehensive perspective on past studies, the document analysis method aims to provide a guiding framework for future research by revealing the missing aspects in the field of science education for special education students.

Screening Method and Determination of Selection Criteria

In this research, document analysis method was used and in the first stage, evaluation criteria and keywords to be used in this direction were meticulously determined in order to determine the studies to be examined. The scope of the research includes studies conducted in the field of science education for individuals with special educational needs between 2000 and 2023. These studies include articles published in refereed journals and theses open to international access. Based on the criteria determined, keywords suitable for the topics that the research focussed on were selected both in Turkish and English, and it was tried to reach the relevant literature at national and international level.

The English keywords used in the literature review phase of the study included 'science education for special education students', 'science education within the scope of inclusive education', 'science education for individuals with autism spectrum disorder' and 'science education for people with disabilities'. The Turkish keywords were 'science education for individuals with special education needs', 'science education within the scope of inclusive education', 'science education for individuals with autism spectrum disorder' and 'science education for people with disabilities'. These keywords were used effectively in the screening process in order to examine the research topic in depth and to access the studies in the literature.

The systematic review process aimed to select the studies included in the scope of the research in accordance with the determined criteria and to analyse these studies in detail. In this context, both national and international sources were utilised and data were collected to provide a comprehensive picture of the current situation in the field of science education for individuals with special educational needs. This method aims to create a framework that will contribute to the literature and serve as a reference for future research.

Screening Process

In this study, a comprehensive literature review was conducted by using the keywords determined in order to access the articles on 'science education for individuals with special educational needs'. ISI Web of Science, EBSCOHost, Science Direct, Scopus, ERIC databases and Google Scholar search engines

were utilised in the search process. The identified keywords were systematically applied to identify the literature appropriate to the themes that the research focussed on. In order to determine whether the studies obtained were directly related to the research topic, the titles and contents of the relevant studies were examined in detail. In this process, a meticulous elimination was made in order to eliminate the studies outside the scope of the research. At the end of the analysis, 26 studies directly related to the research topic were included in the scope of the study. In addition, the bibliographies of the sources included in the study were analysed to identify the studies that were overlooked or not reached during the screening process. However, as a result of this process, no additional study that could be suitable for the scope of the study was found. This comprehensive screening and elimination process ensured that only studies that would contribute to the subject were included in the study and supported the integrity of the literature obtained.

Analysis Process

In the analysis phase, the studies included in the research were examined in detail in line with various categories. These categories were structured as the research topic addressed by the study, methods used, characteristics of the study group, data collection tools, data analysis techniques, findings and conclusions drawn.

Each study was analysed in depth in order to understand the specific context of the research topic and the appropriateness of the methods used in terms of validity and reliability were reviewed. The study groups were analysed in terms of the demographic and qualitative characteristics of the participants, and the compatibility of these groups with the objectives of the study was examined. In addition, data collection tools provided detailed information about the methods used in the studies and shed light on the ways in which the research processes were structured. Data analysis methods were subjected to a critical evaluation process in terms of the accuracy and general validity of the results obtained.

In the category of findings and conclusions, the prominent implications of each study and the contribution of these implications to the literature were discussed in detail. This process provided a holistic evaluation of the studies within the scope of the research and enabled the data obtained to be analysed in a comprehensive and systematic manner.

Conclusıon and Dıscussıon

The articles identified at the end of the screening process carried out in line with the criteria defined in detail in the method section of the study were subjected to a detailed analysis in terms of basic features such as publication year, author names, article titles and publication information. This analysis enabled a comprehensive evaluation of the relevant literature and ensured

that the research findings were presented in an organised manner. The data obtained were summarised in a systematic way and the results are compiled and presented in Table 1. This process aimed to make sense of the existing body of knowledge in the research area and to strengthen the context of the study.

Tablo 1. İncelenen makale listesi

	Year	Authors	Title	Journal
1	2004	Chard, D.	Maintaining the Relationship Between Science and Special Education.	Journal of Learning Disabilities
2	2007	Eni-Olorunda, J., & Oyundoyin, J.	Teaching Science To Students With Special Needs.	International Journal of Emotional Psychology and Sport Ethics
3	2012	Villanueva, M., Taylor, J., Therrien, W., & Hand, B.	Science education for students with special needs	Studies in Science Education
4	2013	McGinnis, R.	Teaching Science to Learners With Special Needs	Theory Into Practice
5	2015	Alber-Morgan, S., Sawyer, M., & Miller, H.	Teaching Science to Young Children with Special Needs	Research in Early Childhood Science Education
6	2015	Thornton et al.	Effects of collaborative pre-teaching on science performance of high school students with specific learning disabilities	Education and Treatment of Children
7	2015	Knight et al.	An exploratory study using science e-texts with students with autism spectrum disorder	Focus on Autism and Other Developmental Disabilities
8	2015	Ozguc and Cavkaytar	Science education for students with intellectual disability: A case study	Journal of Baltic Science Education
9	2016	Mulvey, B., Chiu, J., Ghosh, R., & Bell, R.	Special Education Teachers' Nature of Science Instructional Experiences	Journal of Research in Science Teaching
10	2016	Koomen	Inclusive science education: Learning from Wizard	Cultural Studies of Science Education
11	2016	Carnahan et al.	Increasing comprehension of expository science text for students with autism spectrum disorder	Focus on Autism and Other Developmental Disabilities
12	2017	Kim	Multimodal modeling activities with special needs students in an informal learning context: Vygotsky revisited	EURASIA Journal of Mathematics, Science and Technology Education
13	2018	Butler, R.	Teaching science to students with special educational needs	The School Science Review
14	2018	Knight et al.	Scripted and unscripted science lessons for children with autism and intellectual disability	Journal of Autism and Developmental Disorders

15	2019	Garwood et al.	Improving persuasive science writing for secondary students with emotional and behavioral disorders educated in residential treatment facilities	Behavioral Disorders
16	2020	Boyle, S., Rizzo, K., & Taylor, J.	Reducing Language Barriers in Science for Students with Special Educational Needs	Asia-Pacific Science Education
17	2021	Maryanti, R., Bayu, A., Nandiyanto, D., Hufad, A., & Sunardi, S.	Science Education for Students with Special Needs in Indonesia: From Definition, Systematic Review, Education System, to Curriculum	Indonesian Journal of Community and Special Needs Education
18	2021	Kizilaslan et al.	Improve learning with hands-on classroom activities: Science instruction for students with visual impairments	European Journal of Special Needs Education
19	2022	Zorluoğlu, S., Devecioğlu, G., & Kızılaslan, A.	Content Analysis of Science Education Research in Special Education Journals	Journal of Science Learning
20	2022	Maryanti, R., & Asjjari, M.	Family as An Educational Environment That Can Provide Science Education for Children with Special Needs	Indonesian Journal of Community and Special Needs Education
21	2022	Kontopoulou, M., Papageorgiou, V., Malli, E., Mertsioti, L., & Drigas, A.	Special education in science Teaching	Technium Education and Humanities
22	2022	Adu-Boateng and Goodnough	Examining a science teacher's instructional practices in the adoption of inclusive pedagogy: A qualitative case study	Journal of Science Teacher Education
23	2022	MallidisMalessas et al.	Teaching physics to students with intellectual disabilities using digital learning objects	Journal of Special Education Technology
24	2023	Terceño, E., & Greca, I.	Teaching science to students with special educational needs: a systematic review of science teaching-learning approaches in regular and special education settings.	International Journal of Science Education
25	2023	Yaman, H.	A Thematic Review of Studies on Specific Learning Disabilities in Science Education	Participatory Educational Research
26	2024	Scott, T., & Nelson, C.	Science and Special Education: A Foundational Relationship	Exceptionality

Detailed information on the topics, methods used, data collection tools and study groups of the articles analysed in the research process are presented in Table 2. The ordering of the articles in Table 2 is consistent with the ordering of the articles in Table 1.

Table 2. Topics, Methods, Data Collection Tools, and Study Groups of the Relevant Article

	Study Topics	Method and Data Collection Tool	Study Group
1	The study examines the role of scientific approaches in the field of learning difficulties, the use of scientific methods in special education practices, and their impact on preventing learning difficulties and reducing referral rates to special education.	The research adopts a systematic approach by reviewing findings from the literature and practical applications, evaluating the impact of scientific data on educational outcomes. A literature review method was employed to analyze existing research.	-
2	The study emphasizes the importance of science education for individuals with special needs and explores the historical development of science education in Nigeria's curriculum.	Through a literature review, the study investigates how science education should be addressed as a fundamental right for individuals with special needs.	-
3	This study examines the low achievement levels of students with special needs in science and strategies and support required to enhance their success.	Using meta-analysis and applied research methods, the study analyzed how inquiry-based science instruction can support students with special needs. Data were drawn from meta-analysis results and examples of applied science instruction.	-
4	This study explores evidence-based adapted instructional strategies to make science education more accessible and meaningful for individuals with special needs, focusing on social justice in this field.	A literature review method was employed to examine existing research and practices in science education for individuals with special needs. Data were collected from relevant research articles, reports, and policy documents.	-
5	This study aims to present evidence-based approaches to science education by evaluating experimental studies that explore effective strategies for teaching science to young children with special learning needs.	A literature review analyzed experimental studies from the past 20 years on science education for children with special needs, focusing on 12 studies published in scientific databases.	-
6	The study investigates the effectiveness of a cooperative pre-teaching method in improving the science achievement of high school students with specific learning disabilities (SLD) in general biology classes.	An experimental study using a single-case multiple-probe design across science units was conducted. Data were collected from daily biology test scores, comparing performance before and after implementing the cooperative pre-teaching method.	Two high school students diagnosed with SLD
7	This study examines the impact of supported electronic text (eText) tools, particularly the Book Builder™ application, on the comprehension of science-related texts by students with autism spectrum disorder (ASD).	Designed as a pilot study, an experimental method with a multiple-probe ABCD embedded design was applied. Data were collected through assessments measuring vocabulary knowledge, literal comprehension, and application questions. Teacher and student satisfaction reports were also obtained.	Four students diagnosed with ASD

8	The study aims to identify needs and challenges in teaching Science and Technology to students with mild intellectual disabilities in a special education middle school.	A qualitative case study method was adopted, and data were collected using various qualitative tools, including semi-structured interviews with teachers, students, and parents, researcher journals, classroom materials, field notes, and video recordings.	Two teachers, 11 students, and their parents
9	The study explores special education teachers' beliefs and practices regarding science education, the nature of science, and inquiry-based teaching, with a focus on their professional development experiences.	A cross-case analysis was conducted on four special education teachers, examining their professional development experiences over a semester. Data were collected through pre/post-test surveys, video recordings of lessons, reflective guidance logs, and end-of-term interviews.	61 preschool and primary school teachers
10	The study investigates the learning experiences of a student with special needs in a mainstream classroom during life sciences lessons, framed within disability studies in education.	A 13-week case study was conducted, analyzing the student's classroom experiences using qualitative methods. Data were collected through observations, interviews, student work, and video recordings of teaching and learning processes via CETP-COP.	One student with special needs
11	The study evaluates the effects of a text structure intervention package on improving science text comprehension for high-functioning students with autism.	A single-case experimental design with multiple baselines was used. Data were gathered through performance assessments during and after intervention and teacher evaluations of implementation fidelity. Participants' feedback on the intervention was also collected.	Three high-functioning autistic high school students and one special education teacher
12	The study addresses the development of participatory learning environments around the theme of "day and night" for students with special needs in Singapore, grounded in Vygotsky's theoretical perspectives.	Conducted as design-based research, the study aimed to move away from traditional astronomy teaching to create participatory learning environments. Data were collected through observations, multimodal activity outputs, and reflective documents on students' learning processes.	Students with diverse cognitive and social needs
13	The study discusses effective strategies in teaching science to students with special education needs, aiming to address common learning challenges in middle school classrooms.	The study was conducted in a workshop format, sharing methods developed through over 20 years of teaching experience. Data were collected from observations, experience reports, and student feedback on the applied methods.	-
14	This study evaluates the effectiveness, efficiency, and teacher preferences regarding scenario-based and non-scenario-based lesson plans in an elementary science curriculum for students with intellectual disabilities and autism spectrum disorder.	An experimental design was used to compare scenario-based and non-scenario-based lesson plans based on criteria such as science comprehension, the number of sessions needed to meet criteria, and average lesson duration. Data were collected from science comprehension assessments, session recordings, and teacher feedback.	Elementary students with intellectual disabilities and ASD

15	The study focuses on developing persuasive writing skills among students experiencing complex trauma and emotional-behavioral disorders in special education settings.	Conducted using a multiple-probe, multiple-baseline design, a science teacher implemented class-wide instruction based on a self-regulated strategy development model. Data were collected through text analyses, word counts, and holistic quality scores of students' writings, alongside participant feedback for social validity.	11 secondary students with emotional-behavioral disorders
16	This study examines multimodal representations and communication technologies to reduce language barriers in teaching science to students with special education needs.	A literature review analyzed proposed methods and resources for reducing language load in science instruction using findings from existing research and meta-analyses within the Universal Design for Learning (UDL) framework.	-
17	This study aims to determine the quality and scope of science education provided by families to students with special needs.	Conducted using qualitative research methods, the study deeply explored the roles and perceptions of families in science education. Data were collected through semi-structured interviews with families and students with special needs, evaluating attitudes and practices in science education.	A group of students with special needs and their families
18	This research explores the contributions of instructional materials and activities designed to support visually impaired students in coping with visually intensive and complex concepts in science classes.	The study was conducted in three phases: exploratory case study, material and activity design, and evaluation-focused case study. Data were collected through observations, interviews, and performance assessments of students.	Visually impaired students
19	This research aims to examine studies on science education in special education indexed in the ERIC database, analyzing topics, methods, sample sizes, data collection and analysis tools, disability types, and educational levels.	The study employed content analysis, reviewing articles retrieved from the ERIC database using the keywords "special education" and "science education." Data were extracted and analyzed in tables and graphs.	-
20	The research identifies instructional methods, curriculum, and practices used by teachers in science education for special needs students in Indonesia.	Conducted using qualitative methods, data were collected through observations and interviews with teachers.	Children with mental and physical disabilities
21	This study examines the role of information and communication technologies (ICT) in special education and their impact on individuals with diverse learning needs, including autism, visual impairment, hearing loss, sensory and physical disabilities, and dyslexia.	The study analyzed existing literature and case studies on ICT in special education. Data were obtained from previous studies, literature reviews, and applications of supportive technologies.	-

22	This study investigates the inclusive science pedagogy practices and tensions encountered by a special education science teacher in an urban high school, framed within the Universal Design for Learning (UDL) theoretical framework.	Designed as a qualitative case study, data were collected through interviews, observations, and document analysis to describe the teacher's experiences in implementing inclusive science pedagogy.	-
23	This research evaluates the impact of Digital Learning Objects (DLOs) in the form of interactive simulations on the physics education of students with intellectual disabilities.	Using an AB single-case experimental design, the study analyzed the effects of DLOs through sessions measuring scientific terminology and understanding of physical phenomena, alongside a social validity assessment.	Students with intellectual disabilities
24	This study systematically reviews didactic approaches and practices in science education for students with special needs, focusing on intervention methods developed in recent years.	A systematic review analyzed didactic suggestions and practices in the literature. Data were drawn from 54 publications, with 27 selected for detailed analysis.	Students from 27 application centers
25	This study thematically reviews research on science education for students with specific learning difficulties (SLD) conducted between 2009 and 2021, focusing on their development and the effectiveness of teaching methods.	Thematic content analysis was employed to analyze studies retrieved from relevant databases based on parameters such as purpose, methods, sample group, data collection tools, results, and recommendations.	-
26	This research examines the fundamental role of the scientific method in special education, including its importance in identifying best practices for disadvantaged and disabled students. The study also evaluates critical perspectives on the scientific method and potential risks.	A conceptual analysis was conducted, reviewing relevant literature and critically analyzing scientific methodologies in special education.	-

Table 2 provides a framework that systematically addresses various aspects of research on science education of individuals with special needs. The table categorises different research topics, methods used, data collection tools and study groups in detail. Prominent research topics include the role of scientific methods in special education, accessibility of science education and effective teaching strategies, interventions for various disability groups, and technology-assisted education practices. The methods used in the studies are generally literature reviews, qualitative and quantitative methods, experimental designs and meta-analyses. Data collection tools range from information collected from literature sources to field studies and individual observations. In addition, different measurement techniques such as teacher and student feedback, video recordings and performance assessment tools were also used. The study groups included different disability groups such as autism spectrum

disorder, intellectual disability, visual impairment, hearing loss, and in most studies both students and teachers were involved. The table emphasises that science education is not only a knowledge transfer process for individuals with special needs, but also needs to be addressed from the perspectives of social justice, accessibility and individual development. In this context, it provides an important source of information on how scientific and pedagogical approaches to the education of individuals with special needs can be made more effective to meet their learning needs. The fact that the research is carried out with various methods and groups provides a broad perspective on the subject and provides a comprehensive guide on how science education can be made more efficient in the context of special education.

Table 3. Data analysis methods of the articles analysed within the scope of the research and the levels of cognitive reflection identified/examined

	Data Analysis Method	Findings
1	Data obtained from the literature were analyzed using content analysis, examining the thematic impacts of scientific approaches	The study revealed that scientific methods effectively prevent learning difficulties and reduce referral rates to special education. However, it emphasized the potential for undesirable outcomes if science is misapplied.
2	Content analysis was used to evaluate existing studies on the importance of access to science education for individuals with special needs.	The findings highlighted that access to science education for individuals with special needs should be considered a fundamental human right. Appropriate teaching strategies and materials are critical for their education.
3	Data were analyzed using content and descriptive analysis to evaluate the effects of support and scaffolding practices in structured inquiry teaching.	The study demonstrated that appropriate support and scaffolding in inquiry-based science teaching significantly enhance science achievement among students with special needs. Notable supports included guided learning, the use of visual materials, and writing strategies.
4	Content analysis was employed to assess the effectiveness of curriculum adaptations, teaching, and assessment processes.	The study concluded that adapted science curricula and teaching strategies are critical for promoting educational equity among individuals with special needs. Evidence-based adaptations by science teachers were found to enhance students' science achievement.
5	Content analysis was used to identify and thematically classify widely used strategies and tactics for effective science education.	The review indicated that hands-on and inquiry-based teaching strategies are effective. These strategies should be combined with tailored support and open instruction elements to address individual needs. Positive effects of science education on children facing academic challenges were also noted.
6	Visual analysis was used to test functional relationships, comparing students' test performance before and after intervention.	The cooperative pre-teaching method led to significant improvements in students' daily biology test performance, demonstrating a strong relationship between the method and academic success.

7	Experimental design data were evaluated using visual analysis and descriptive statistics.	Modifications to the Book Builder™ application achieved high treatment fidelity and received positive feedback from both teachers and students. The tool improved vocabulary knowledge, literal comprehension, and application skills.
8	Data were analyzed using content analysis with NVivo 10 software.	Findings revealed a lack of high-tech tools in the school, a need for improved attitudes among special education teachers toward the importance of Science and Technology classes, and the necessity of supporting teachers with differentiation and adaptation techniques.
9	Qualitative and quantitative analysis methods were employed to assess participants' progress and practices in detail.	Teachers' understanding of the nature of science improved, and they implemented inquiry-based teaching. Lessons were adapted to student needs, though limited references to individual needs and IEPs were noted.
10	Data were analyzed using qualitative methods and synthesized within a thematic framework.	The student's science learning experiences were shaped by a duality of autonomy and dependency. The interdisciplinary literacy development contributed to a fragmented learning process, highlighting the fragile yet functional nature of inclusive education.
11	Changes in student performance were measured and analyzed during intervention and maintenance phases.	The intervention package was highly effective for all participants during both intervention and maintenance phases. Teachers implemented the intervention with high fidelity, and all participants reported the intervention as beneficial for understanding science texts.
12	Data were evaluated using content analysis, analyzing themes reflecting students' understanding of astronomy, socio-emotional experiences, and multimodal learning processes.	Interdisciplinary and multimodal modeling activities supported the development of multiliteracy skills. Digital and multimodal resources positively influenced students' socio-emotional experiences and integrated everyday experiences with scientific understanding, fostering higher cognitive functions.
13	The effectiveness of strategies was assessed using content analysis, focusing on their impact on student engagement, learning levels, and continuity.	Individualized instructional strategies had positive effects on learning and engagement among students with special needs. These strategies increased interest in science classes and fostered active participation.
14	Quantitative analysis methods were used to evaluate effectiveness and efficiency, while teacher preferences were analyzed descriptively.	Both scenario-based and non-scenario-based lesson plans effectively improved science comprehension. Non-scenario-based lesson plans were found to be more efficient in achieving target behaviors with fewer sessions. Teachers preferred non-scenario-based plans for their flexibility and adaptability.
15	Data were analyzed using Tau-"U" statistics to evaluate the magnitude of effects on various dimensions of writing performance.	Large effects were observed in the foundational elements of persuasive writing (Tau-"U" = 0.97), word count (Tau-"U" = 0.96), and holistic quality of writing (Tau-"U" = 0.97). Participants reported high levels of social validity for the strategy development model.

16	Literature review and content analysis methods were employed to categorize data for identifying appropriate science teaching strategies for students with special needs.	Text-heavy and language-intensive requirements in science teaching posed challenges for students with special needs. Multimodal representations, artistic applications, and communication technologies were found to reduce these barriers, making science learning more accessible.
17	Data were analyzed using content analysis to identify common themes in family perceptions and practices related to science education.	Most families delegated responsibility for science education entirely to school teachers. Families viewed science as overly complex due to its association with formulas and numbers, despite its practical relevance to everyday natural phenomena.
18	Data were analyzed using qualitative content analysis to assess the impact of materials designed for students' needs.	Visually impaired students were easily distracted by detailed and complex materials, making simple and focused materials more effective.
19	Data from articles were analyzed using thematic content analysis, categorizing findings for interpretation.	The study found limited interest in conducting research on science education for individuals with special needs among both special education and science education researchers. Research predominantly focused on STEM, with limited studies in physics, chemistry, and astronomy. Semi-experimental and multiple-design methods were the most common quantitative research approaches.
20	Data were analyzed using qualitative content analysis, categorizing the effects of ICT in education.	ICT and assistive technologies were found to not only overcome environmental barriers but also enhance personal and social expression and communication. These technologies increased accessibility and inclusivity in education, particularly benefiting students with autism and dyslexia.
21	Data were analyzed using a continuous comparative method in MAXQDA software with an inductive approach.	Inclusive science pedagogy practices focused on increasing student engagement, representing curriculum in diverse ways, and providing opportunities for students to express scientific understanding. Challenges included inadequate resources, rigid curricula, dependence on standardized tests, and lack of professional development.
22	Functional relationship analysis was used to evaluate changes in students' learning processes.	Digital Learning Objects (DLOs) improved students' understanding of scientific terminology and physical phenomena. Social validity assessments indicated positive effects on learning quality and engagement, with high satisfaction reported by students.
23	Publications were categorized by teaching strategies and methods and analyzed using qualitative content analysis.	Open instruction was a core approach in special education centers, while diverse experiences and methods were prominent in general education centers. Both settings employed learner-centered teaching, emphasizing inquiry-based and hands-on activities. However, the limited number of publications indicated that research in this area remains scarce.
24	Data were evaluated through thematic analysis, systematically categorizing methods, findings, and recommendations.	Open instruction was a core approach in special education centers, while diverse experiences and methods were prominent in general education centers. Both settings employed learner-centered teaching, emphasizing inquiry-based and hands-on activities. However, the limited number of publications indicated that research in this area remains scarce.

25	Data were evaluated through thematic analysis, systematically categorizing methods, findings, and recommendations.	Studies on science education for students with specific learning difficulties (SLD) were limited. Most focused on elementary-level students' academic performance and conceptual understanding using quantitative methods. Social and behavioral challenges in the context of science education were largely neglected.
26	Data were analyzed through literature review and critical evaluation, comparing strengths and weaknesses of the scientific method.	The study highlighted the scientific method as a fundamental tool for designing effective educational programs and services for individuals with disabilities. Rising skepticism towards the scientific method, influenced by cultural relativism, poses risks to the effectiveness of special education practices for disadvantaged students.

Table 3 presents the data analysis methods used in academic studies on science education of individuals with special needs and the findings of these studies in detail. The studies cover a wide range of methods such as content analysis, thematic analysis, descriptive statistics, visual analysis and experimental designs to examine the effect of scientific approaches on the cognitive reflection levels of individuals in the educational processes in the context of science education.

Table 3 reveals important findings in different dimensions such as the effectiveness of scientific methods in preventing learning difficulties, access to science education, inquiry-based instruction, differentiated instructional strategies and technology-supported materials. The general findings of the studies show that evidence-based and adapted instructional strategies have a critical role in facilitating learning processes for individuals with special needs. In addition, it was emphasised that failure to use scientific approaches appropriately may lead to unintended consequences and that educational policies should provide more guidance in this context.

In terms of data analysis methods, content analysis and thematic analysis were frequently used in literature reviews and when working on pedagogical adaptations, while experimental designs were preferred to measure the direct effects of teaching strategies. Visual analysis and statistical methods were effective in assessing students' science achievement and the effectiveness of the intervention packages.

Research has shown that simplifying instructional materials and overcoming language barriers with multimodal representations support the learning process of individuals with special needs. However, in some studies, mismatches between the diversity of instructional strategies and practices in special education settings were noted. This situation shows once again the necessity of increasing the professional development of teachers in the field of science education.

In general, the table shows the importance of research addressing the cognitive and social needs of individuals with special needs in science education and the wide spectrum of methods used in studies in this field. However, the limited number of studies in this field emphasises the need for more comprehensive studies. The findings clearly reveal that teaching methods should be continuously improved in order to increase equality of opportunity in special education.

Table 3. Data analysis methods of the articles analysed within the scope of the research and the levels of cognitive reflection identified/examined

Table 4. Main conclusions reached in the articles analysed within the scope of the research

	Main Results
1	The correct and effective use of scientific approaches is critical for improving the educational and social outcomes of students with learning difficulties.
2	Denying access to science education for individuals with special needs constitutes a violation of fundamental human rights. Thus, providing appropriate learning environments and instructional tools is of paramount importance.
3	Incorporating scaffolding and support mechanisms into inquiry-based science teaching is essential for ensuring the success of students with special needs in science education. These methods have been successfully tested in inclusive classrooms.
4	To improve the accessibility of science education for students with special needs, curriculum and instructional practices must be adapted. Further support and policy development are required to encourage science teachers to adopt research-based practices. The need for increased research in this area is emphasized.
5	Science education for young children with special needs can be made more effective through evidence-based strategies and individualized support. Future research is recommended to diversify science education practices and provide applied support to teachers.
6	Cooperative pre-teaching is an effective method for enhancing the science achievement of students with specific learning difficulties in general education settings. The study highlights the need for future research to expand the application of this method and test it with larger student groups
7	Supported electronic text tools, particularly for students with autism spectrum disorder (ASD), are effective in helping them comprehend science content. The study concludes with recommendations for testing these tools with larger samples and improving their design.
8	To make Science and Technology classes more inclusive, teaching environments should be technologically enriched, and teachers should be equipped with appropriate pedagogical techniques for the special education context. Strategies to enhance the scientific literacy of special education students should also be developed.
9	Professional development focusing on the nature of science and inquiry-based learning can raise the expectations of special education teachers for students with special needs. However, professional development programs should provide greater support in planning processes and in developing strategies tailored to specific student needs. Support for understanding the roles of general and special education teachers in inclusive classrooms is also recommended.
10	Supporting students with special needs in inclusive classrooms requires focusing on their strengths, intentionally utilizing interdisciplinary literacy strategies, and involving students in decision-making processes.
11	The intervention package was found effective in supporting the comprehension of science texts by high-functioning students with autism. Future research should address the scalability and integration of such interventions into teaching practices.
12	The study underscores the importance of multimodal and participatory learning environments for the cultural and cognitive development of students with special needs. These approaches offer an effective way to deepen scientific understanding and enrich socio-emotional experiences.

13	The research highlights the applicability and benefits of effective strategies in science learning for students with special needs. The workshop's shared methods are concluded to contribute to developing more effective teaching approaches for these students.
14	The study found that both scenario-based and non-scenario-based lesson plans are effective for students with intellectual disabilities and autism spectrum disorder. However, non-scenario-based plans were deemed more efficient and preferred by teachers. These findings provide significant implications for the design of special education curricula and teacher training.
15	The study demonstrated that persuasive writing instruction based on a self-regulated strategy development model is effective for students experiencing complex trauma. The applicability of such interventions in residential treatment facilities was emphasized, and future research directions for this student population were discussed.
16	The study shows that reducing language barriers in science teaching for students with special needs enhances learning experiences. The use of multimodal strategies and technologies increases access to scientific content, making science education more inclusive. The study offers resources and strategy recommendations for teachers.
17	The study highlights the importance of active parental involvement in the science learning of students with special needs. It suggests that science education offers opportunities not just for academic processes but also for exploring natural phenomena. Awareness-raising programs for families are recommended.
18	Instructional materials and activities designed for visually impaired students were found to facilitate understanding of scientific concepts and contribute to their learning processes. Simple materials focusing on a few key ideas proved more effective than detailed and complex ones.
19	The study found limited research in the field of science education within special education, with STEM-focused topics being more prevalent. It emphasizes the need for more research in underexplored disciplines like physics, chemistry, and astronomy.
20	The study highlights the need to develop more appropriate and needs-responsive instructional materials and methods to enhance the success of students with special needs in science learning. Current methods were found insufficiently effective for this population.
21	ICT has a broad range of applications in special education, significantly contributing to improvements in individuals' educational and social lives. The study concludes that ICT holds great potential for creating more effective and inclusive educational environments by addressing individual differences.
22	The study draws attention to the challenges teachers face in implementing inclusive science pedagogy. It emphasizes the importance of professional development for science teachers and teacher candidates and offers recommendations for flexible curriculum design and increased resources. Structural and educational reforms to support inclusive pedagogy are suggested for future research.
23	Digital Learning Objects (DLOs) were found to be effective tools for the physics education of students with intellectual disabilities, positively influencing their learning processes. More DLOs should be designed for students with intellectual disabilities in future research.
24	The study highlights the need to offer more opportunities for students with special needs in science learning and to develop teaching practices that consider the diversity of all learners. Strengthening the evidence base and conducting further research for more inclusive science education is emphasized.
25	The study emphasizes the need for diversification in research on students with specific learning difficulties (SLD) and suggests conducting in-depth analyses for different sample groups, such as science teacher candidates. Addressing the social and behavioral challenges of SLD students in the context of science education is proposed as a means of developing more inclusive and effective science education practices.
26	The scientific method is an indispensable tool for determining and sustaining effective practices in special education. The study warns that distancing from evidence-based practices poses significant risks for disadvantaged students. Supporting educational policies grounded in scientific methods is recommended.

Table 4 summarises the main findings of research on science education for individuals with special needs in a systematic way. Studies reveal that scientific methods and pedagogical adaptations have a critical role in supporting

individualised learning processes in the special education context. Research shows that the educational and social experiences of individuals with special needs can be improved through the implementation of strategies that reduce learning difficulties and increase learning achievement.

It is emphasised that science education is a right for individuals with special needs and it is stated that not providing access to educational processes for these individuals can be considered as a violation of basic human rights. Various studies show that strategies such as inquiry-based teaching, co-operative pre-teaching and the use of technological tools increase the participation of individuals in science learning and make learning processes more inclusive. Among these strategies, it is particularly noteworthy that supported electronic text tools and multimodal representation methods improve learning experiences by reducing language barriers.

The table also emphasises the importance of teaching materials and curriculum adaptations for individuals with special needs in improving accessibility and learning quality. It was revealed that science teachers need to adopt research-based and individualised strategies and that professional development programmes for teachers should be expanded in this process. It is emphasised that special education teachers and general education teachers should work together to strengthen inclusive pedagogical practices, especially in inclusive classrooms.

Research suggests that teaching strategies should be effective as well as focusing on the strengths of individuals with special needs and ensuring their participation in decision-making processes. In addition, the benefits of multimodal and interdisciplinary learning approaches that support students' social-emotional development and scientific literacy are highlighted. In particular, it was stated that STEM-oriented studies should be widespread, and more research is needed in areas such as physics, chemistry and astronomy.

The findings in the table clearly reveal that research on science education of individuals with special needs should be increased and more inclusive practices should be developed. In the studies in this field, it was emphasised that the scientific method is indispensable and the integration of this method into education will improve the learning processes of disadvantaged individuals. In this context, it is suggested that future research should cover wider groups, teaching methods should be diversified and science-based practices should be supported by educational policies.

Comments and Suggestıons

This study makes an important contribution by providing a systematic review of science teaching research for children with special educational needs and identifying general trends and knowledge gaps in the field. Science

education is defined as a fundamental field that develops individuals' critical thinking skills and facilitates their understanding of the natural world; however, the unique challenges and limitations faced by individuals with disabilities in science learning processes are addressed. The study emphasises that the principles of equality and inclusion are of vital importance in the education of these individuals and in this context, science education should be adapted according to individual needs.

The comprehensive databases used in the literature review process ensured that the results of the study were based on a wide academic range and the content analysis of the selected publications in four main categories made it possible to systematically address the methods and strategies used in science teaching. The reviewed publications show that technology-supported instructional materials, individualised strategies and inclusive pedagogical approaches have positive effects on the science learning outcomes of students with special needs. These findings reveal that science education is not only an academic but also a social transformation tool.

It is valuable that the study draws attention to the relationship between research methodologies and teaching practices in creating a more inclusive learning environment for individuals with special educational needs. In this direction, it is suggested that educational interventions should be individualised and various data collection tools should be used, and teaching strategies should be handled with a multidimensional approach. Considering the findings of the study, the following suggestions can be made:

- In the study, it was stated that the methods used in the researches on science education were handled systematically. Future studies can provide a more comprehensive perspective on the effectiveness of teaching strategies by focusing on mixed research designs that blend both qualitative and quantitative methods.
- Considering the effects of technological tools on science learning of individuals with special needs, innovative approaches in this field should be further investigated. In particular, how developments such as artificial intelligence-supported learning platforms and virtual reality technologies transform individual learning experiences can be examined.
- The study emphasises the importance of curriculum adaptations to increase the inclusiveness of science education. In this direction, it is suggested that teachers should be supported more in the processes of creating individualised education plans (IEPs) and professional development programmes should be increased to adopt inclusive pedagogy.
- Considering the fact that science education is a process that continues not only in the school environment but also at home, it is important to

involve families in this process. Guidance programmes and awareness-raising campaigns can be organised for families in the context of science education.

- Teaching science education in an integrated manner with other disciplines can make learning experiences more meaningful. In particular, the inclusion of mathematics, technology and art in science education can enrich students' learning processes.
- In the study, it was stated that there is limited research in science fields such as physics, chemistry and astronomy. In the future, comprehensive studies should be conducted in these areas, especially for different disability groups such as visually impaired, hearing impaired and individuals with autism spectrum disorders.

Longitudinal studies should be conducted to examine the long-term effects of science education interventions. These studies can evaluate the changes in individual learning outcomes over time and the effects of science education on individuals' career choices.

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THE EFFECT OF NATURE OF SCIENCE ACTIVITIES PREPARED WITH TECHNOLOGY INTEGRATION ON PRE-SERVICE TEACHERS' UNDERSTANDING OF SCIENCE

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Abstract

This study aims to evaluate the changes in pre-service science teachers' scientific understanding and attitudes towards web-based instruction by examining the effect of technology-supported activities on their understanding of the nature of science (NOS). The study was conducted on 2nd and 3rd year students studying in the science teaching programme in the 2024-2025 academic year. In the study, the Nature of Science Scale (NOS) was used to measure the participants' views on the nature of science.

A quasi-experimental design with pretest-posttest control group was adopted as the research method. The data obtained with the NOS on the students in the experimental and control groups were analysed and the paired dependent t-test was applied using SPSS software to evaluate statistical significance. As a result of the study, it was observed that there was a significant difference between the post-test results of the experimental and control groups. These differences were analysed in detail in various sub-dimensions of NOS.

According to the findings, it was determined that technology-supported activities positively improved pre-service teachers' understanding in sub-dimensions such as openness of scientific knowledge to change, experiment-based nature of science, the role of creative imagination in science, scientific method, social and cultural values in science, scientific models, science and technology relationship. The study reveals that these activities are effective in developing pre-service teachers' scientific thinking skills and that the integration of web-based technologies in education plays a critical role in this process.

In conclusion, it can be said that technology-supported IS activities enable pre-service science teachers to gain a more comprehensive and deeper understanding of science, which is an important tool in improving the quality of science education. The results of the study provide important implications for the integration of technology-supported learning approaches into teacher education.

Keywords: Science education, Nature of science, Educational technologies, WEB 2.0 tools, Student teachers

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Introductıon

Since scientific knowledge has a variable and dynamic nature, an in-depth understanding of this nature requires a comprehensive knowledge of the historical evolution of scientific processes (Harizanov & Milanova, 2022). Studying the history of science is indispensable for understanding how science has reached its current level and the transformations it has undergone over time. The nature of science provides a holistic understanding of basic scientific concepts and the principles that shape research processes. In this context, doing science is based on recognising that knowledge is not absolute and can always be reconstructed with new evidence (Bouni et al., 2024). Scientific knowledge is developed through experimentation, observation and logical inferences based on evidence; this reveals the systematic and empirical character of science. Science is also the product of a collective effort, not an individual one (Uyar, Uludağ Kırçıl, Uluçınar Sağır, 2024). Researchers not only carry out their own individual studies, but also analyse, criticise and improve the findings of other scientists. This cooperation ensures that science is a structure that renews itself and reinforces its reliability (Adıyaman, 2019). One of the fundamental elements of scientific progress is the interaction and exchange of information created by this collaboration. Karl Popper defined science as a process based on critical thinking. According to him, science develops by rigorously questioning hypotheses and theories and handling them in a way that is open to falsification. The aim of criticism in this process is to reveal mistakes and deficiencies and to correct these mistakes. The constructive use of criticism enables scientific knowledge to be carried to a higher level and one step closer to the truth. This approach shows that science is a dynamic system that not only collects existing knowledge but also continuously improves it (Popper, 2001).

Knowledge is a multifaceted concept that can be obtained in various ways. Different tools such as reasoning, experimentation, observation, inference, logic, intuition, experience and scepticism are the basic elements used to reach knowledge. However, what makes knowledge special in the scientific context is the unique structure of the scientific method and its functionality in the knowledge production process (Chartier & Rundell, 2016). Science produces testable and verifiable results with a unique systematic approach. This feature is one of the main elements that distinguish science from other types of knowledge. The endeavour to obtain knowledge by applying different methods aims to create a systematic and reliable knowledge base (de Mello, 2020). The most prominent qualities of scientific knowledge include systematicity, objectivity, consistency and controllability. The objective nature of knowledge makes it possible for it to be perceived in the same way by different societies and individuals, and this shows that objectivity is an indispensable principle of science. In addition,

the fact that scientific knowledge is independently verifiable and verifiable reinforces its universality and reliability. In this context, scientific knowledge is no longer a product based solely on individual perceptions; on the contrary, it can be shared and re-evaluated consistently among different individuals and communities through generally accepted methods (Ural, 2016).

Examining the ethical dilemmas, cultural biases and power relations inherent in scientific methodologies enables students to gain a deeper understanding of science as an endeavour carried out by humans within social contexts. The importance of education on the nature and history of science is directly related to the necessity of educating scientifically literate individuals in a complex and technologically driven society (Bancong et al., 2023). Conveying to students the transient and self-correcting nature of scientific knowledge as well as the richness of the historical development process plays a key role in promoting critical thinking skills and recognising the impact of science on society and the natural environment (Pratiwi, Sopandi, & Pangestey, 2023).

The next generation of scientists, thinkers and teachers can support innovation and intellectual discovery in science education by adopting an inquiry-based and multidisciplinary approach. In this process, key elements such as teaching scientific process skills, peer assessment, testing hypotheses, and clarifying the differences between observation and inference are of great importance. Individuals who learn about the nature of science become better equipped to critically evaluate scientific claims, distinguish between correlation and causation, and understand the role of scepticism in the scientific process (Kondrashev et al., 2024).

Investigating the origins of scientific enquiry and the evolution of scientific thinking not only equips students with critical thinking skills, but also enables them to understand the intricacies of scientific discoveries and actively participate in the scientific process. The history of science provides an important tool for understanding the development of scientific knowledge by examining the evolution of scientific ideas over time and how this evolution is influenced by social factors. Treating science as a social phenomenon, this discipline emphasises that science has not only become widespread in a global context, but has also played a fundamental role in technological progress (Alarcon et al., 2023).

The increasingly widespread use of technology in the classroom environment enables the development of understandings about the nature of science from an interdisciplinary perspective by utilising technological tools (Kurashov & Kurashov, 2023). Especially in technologically equipped classrooms, the use of materials such as audio, visual, graphic, table, animation and simulation in courses such as NOS, where abstract concepts and philosophical-based content

are intensively taught, offers significant advantages in terms of addressing different learning styles (Kahyaoğlu, 2011). While these materials can help students perceive complex concepts in a more concrete way, the integration of Web 2.0 tools can also provide pedagogically valuable contributions to the learning process (Atalmiş, 2022).

In order to effectively integrate technology into the educational environment, teachers must first have technological competences. It is of great importance that teachers are equipped with technological pedagogical knowledge in order to effectively integrate digital technologies into their teaching processes (Khut & Shimizu, 2023). This knowledge allows them to enrich their teaching activities, establish stronger communication with students, and effectively manage a modern, technology-driven classroom environment. In addition, teachers are expected to be able to motivate students, transfer knowledge effectively, organise learning processes in a way to ensure students' active participation, and make use of digital tools to assess student achievement (Maryamkhan & Khojirakhan, 2024).

The increasing use of Web 2.0 technologies in education allows individuals to enrich their learning processes by collaborating with various digital environments. Web 2.0 tools not only facilitate individuals' access to information, but also diversify learning experiences by encouraging communication and collaboration among users. The effective use of these tools contributes to the development of teachers' pedagogical competences and enables them to establish a stronger interaction with students (Efe, Turan, & Topsakal, 2022).

In this study, the attitudes of pre-service teachers, who aim to transfer the knowledge and experiences they have gained throughout their professional careers to their students, towards technology-supported NOS activities were examined. In this context, the use of technological tools in NOS teaching reveals the potential to improve pre-service teachers' pedagogical skills and make their learning processes more effective. The findings of the study focus on evaluating pre-service teachers' attitudes towards the use of technology and its reflections on educational practices.

Method

Research Model

In this study, a quasi-experimental design with pretest-posttest control group was used. Quasi-experimental designs refer to research methods designed to understand the cause-effect relationships between variables (Büyüköztürk et al., 2018). These designs are used to evaluate the effectiveness of a variable and to develop various suggestions based on the findings (Ekiz, 2016).

In the research process, after the pre-test application, the experimental group was exposed to a determined independent variable, while no independent

variable was applied to the control group. At the end of the research, the post-test was applied to both groups and the data obtained were compared. This method allows to understand the effect of the independent variable by examining the differences in the experimental and control groups. Quasi-experimental designs are frequently preferred in education and social sciences due to their potential to produce effective results even in cases where control mechanisms cannot be fully provided.

This approach used in the research aims to obtain reliable and valid results by analysing both the effects of the intervention applied in the experimental group and the natural state of the control group.

Study Group

The study group of this research consists of 50 pre-service teachers studying at the Department of Science Education, Faculty of Education, Fırat University in the 2024-2025 academic year. The study group was determined in accordance with the purpose of the research as a population that has the potential to increase pre-service teachers' awareness of scientific knowledge and pedagogical processes.

Data Collection Tools

In this study, the 'Nature of Science Scale' developed by Özgelen (2013) was used to determine pre-service teachers' views on the nature of science. This scale used in the study has a 4-point Likert-type structure and consists of a total of 30 items organised in 11 sub-dimensions. The design of the scale aims to comprehensively evaluate different dimensions related to the nature of science. In the study conducted by Özgelen et al. (2013), Cronbach's alpha internal consistency coefficient was calculated as 0.83 as a result of the reliability analysis of the scale. This value shows that the scale is a highly reliable measurement tool.

Data Collection

In the scope of the study, firstly, the pre-test of the Nature of Science Scale was applied to the pre-service teachers forming the experimental and control groups. This pretest provided a basic measurement to determine the initial levels of the groups and to analyse the effect of the independent variable. The implementation process of the research continued for 10 weeks. During this period, the control group received the traditional course content prepared based on the programme recommended by the Council of Higher Education (YÖK). The experimental group was presented with a course content prepared using technology-supported NOS activities. In these activities implemented in the experimental group, technological tools and programmes determined each week were introduced to the students, and then activities designed using these tools were carried out. The content of the activities aimed to convey NOS

concepts in a more concrete and interactive way by supporting them with technology. At the end of the ten-week implementation period, the Nature of Science Scale was administered to both groups again. This post-test was used to compare the changes in the experimental and control groups and to evaluate the effect of technology-supported activities on pre-service teachers' perceptions of NOS. This systematic process was consistent with the experimental design of the study and allowed for a detailed analysis of the effect of the independent variable.

Analysing the Data

SPSS 21 (Statistical Package for the Social Sciences) software was used to analyse the quantitative data obtained in the study. Before starting the analyses, skewness and kurtosis values were calculated to evaluate whether the data set was normally distributed. These values formed an important basis for determining the extent to which the data set met the assumption of normal distribution. As a result of the analysis of skewness and kurtosis values, data analysis was carried out by selecting appropriate statistical methods.

Results

In this section, the findings obtained by analysing the data obtained within the scope of the research are presented. The findings related to the demographic characteristics of the pre-service teachers who participated in the study are given in Table 1.

Table 1. Findings related to the demographic characteristics of pre-service teachers

Gender	**n**	**Percentage (%)**
Male	19	38,0
Female	31	62,0
Total	50	100,0
Classroom		
1st Class	4	8,0
2 st Class	19	38,0
3 st Class	12	24,0
4 st Class	15	30,0
Total	50	100,0

The findings regarding the demographic characteristics of the study group are presented in Table 1. When the gender distribution is analysed, it is seen that 38% (n=19) of the pre-service teachers are male and 62% (n=31) are female. This distribution shows that female participants are more represented in the study group than male participants.

When the distribution of the grade level was analysed, it was found that 8% (n=4) of the pre-service teachers studied at the 1st grade level, 38% (n=19) at the 2nd grade level, 24% (n=12) at the 3rd grade level and 30% (n=15) at the

4th grade level. This distribution reveals that the study group mainly consists of pre-service teachers at the middle and upper grades.

The results of kurtosis and skewness test for the experimental and control groups are given in Table 2.

Table 2. Kurtosis and skewness test results for the experimental and control groups

Group	Values	Pre Test	Post Test
Experiment	Skewness	1.325	-,891
	ss	,417	,499
	Kurtosis	2,614	0,742
	ss	,830	,833
Control	Skewness	,788	-1,232
	ss	,625	,701
	Kurtosis	1,025	1,118
	ss	,861	,782

The table shows the skewness and kurtosis values for the pretest and posttest results of the experimental and control groups. These values were calculated to evaluate the extent to which the data sets for both groups fulfil the assumption of normal distribution.

In the pre-test data for the experimental group, the skewness value was found to be 1.325 and the kurtosis value was found to be 2.614, indicating that the data exhibited a positive skewness and sharpness. In the post-test, the skewness value changed as -,891 and the kurtosis value changed as 0.742, and it was observed that the data became closer to the normal distribution. This change indicates that the technology-supported NOS activities applied to the experimental group transformed the distribution of the data into a more homogeneous structure.

In the control group, the pre-test skewness value was 0.788 and kurtosis value was 1.025. These values indicate that the data in the control group exhibited a slight positive skewness and a slightly sharper distribution than normal. In the post-test, the skewness value increased to -1.232 and the kurtosis value increased to 1.118. This reveals that the data in the control group exhibited a negative skewness and a more pronounced distribution change in terms of kurtosis.

The differences in skewness and kurtosis values between the experimental and control groups indicate that the experimental group exhibited a more balanced distribution of the data affected by the intervention applied, while no improvement was observed in the control group. These findings suggest that the technology-supported teaching methods used in the experimental group had more positive effects on the data.

The findings regarding the relationship between the pretest scores of the experimental and control groups are shown in Table 3.

Tablo 3. Grup değişkenine göre bilimin doğası ölçeği ön test ve son test puanlarının karşılaştırılması

	Group	n	*X*	ss	t	p
Pre test	Experiment	25	3,42	0,58	1,126	0,416
	Control	25	3,59	0,63		
Post test	Experiment	25	4,47	0,69	**3,566**	**0,022***
	Control	25	4,01	0,74		

Table 3 summarises the results of the statistical analyses of the pre-test and post-test scores of the experimental and control groups. When the pre-test results were analysed, the mean score of the experimental group was (X = 3,42), while the mean score of the control group was (X = 3,59). The difference between the groups was not statistically significant (t = 1,126; p>0,05), indicating that the groups were similar to each other at the initial levels.

When the post-test results were analysed, the mean score of the experimental group was calculated as (X = 4,47) and the mean score of the control group was calculated as (X = 4,01). This difference between the groups was statistically significant (t = 3,566; p < 0.05). This result shows that the intervention or programme applied in the experimental group significantly increased the post-test performance of the participants.

The results indicate that the intervention in the experimental group was effective and the post-test performance of this group was statistically higher compared to the control group. Considering the methodology of the study and the findings, it can be said that the intervention was an effective tool in achieving the targeted outcomes. However, it is recommended to repeat similar studies with a larger sample for the generalisability of the findings.

The t-test results for analysing the participants' pre-test and post-test mean scores on the sub-dimensions of the Nature of Science Scale are presented in Table 4.

Table 4. Comparison of pre-test and post-test scores related to the sub-dimensions of the NOS scale according to group variable

Test type	Sub-dimensions	Group	n	*X*	ss	t	p
Pre test	Scientific knowledge being open to change	Experiment	25	3,40	0,52	2,452	0,025*
		Control	25	3,56	0,61		
	Experiment-based aspect of science	Experiment	25	3,71	0,55	1,887	0,075
		Control	25	3,60	0,45		
	Subjectivity in science	Experiment	25	3,45	0,37	2,891	0,014*
		Control	25	3,85	0,45		
	The place of creative imagination in science	Experiment	25	3,82	0,53	2,796	0,019*
		Control	25	3,51	0,62		
	Social cultural values in science	Experiment	25	3,66	0,44	1,861	0,082
		Control	25	3,52	0,56		
	Observation and inference in science	Experiment	25	3,53	0,71	1,685	0,094
		Control	25	3,69	0,64		
	Scientific hypotheses, laws and theories	Experiment	25	3,57	0,68	1,314	0,136
		Control	25	3,45	0,56		
	Scientific method	Experiment	25	3,98	0,60	1,145	0,154
		Control	25	4,02	0,64		
	Science and technology	Experiment	25	3,63	0,53	1,063	0,253
		Control	25	3,71	0,66		
	Scientific models	Experiment	25	3,94	0,49	1,543	0,127
		Control	25	3,77	0,72		
	Science	Experiment	25	4,01	0,58	2,014	0,066
		Control	25	3,86	0,50		
	Total	Experiment	25	3,65	0,61	1,034	0,314
		Control	25	3,76	0,54		
Post test	Scientific knowledge being open to change	Experiment	25	4,12	0,47	3,475	0,018*
		Control	25	3,69	0,62		
	Experiment-based aspect of science	Experiment	25	4,54	0,55	4,012	0,000*
		Control	25	3,77	0,35		
	Subjectivity in science	Experiment	25	4,20	0,53	2,947	0,029*
		Control	25	3,79	0,77		
	The place of creative imagination in science	Experiment	25	4,45	0,58	4,156	0,000*
		Control	25	3,62	0,62		
	Social cultural values in science	Experiment	25	4,05	0,74	1,855	0,133
		Control	25	3,91	0,66		
	Observation and inference in science	Experiment	25	3,86	0,62	1,766	0,184
		Control	25	3,53	0,49		
	Scientific hypotheses, laws and theories	Experiment	25	4,33	0,56	3,614	0,024*
		Control	25	3,75	0,37		
	Scientific method	Experiment	25	4,56	0,48	2,996	0,037*
		Control	25	3,99	0,52		
	Science and technology	Experiment	25	4,32	0,64	2,761	0,039*
		Control	25	4,08	0,38		
	Scientific models	Experiment	25	4,17	0,44	1,698	0,099
		Control	25	3,39	0,62		
	Science	Experiment	25	4,50	0,59	2,943	0,022*
		Control	25	4,13	0,63		
	Total	Experiment	25	4,38	0,83	3,594	0,017*
		Control	25	3,94	0,69		

In Table 4, the comparison of the pre-test and post-test scores of the sub-dimensions of the Nature of Science Scale according to the group variable is presented in detail. The analysis reveals that there are significant differences between the experimental and control groups in terms of certain sub-dimensions. Independent t-tests conducted according to the test type show that there are significant improvements in many sub-dimensions, especially in the post-test scores of the experimental group.

When the pre-test results were analysed, significant differences were found between the experimental and control groups in the sub-dimensions of 'Scientific knowledge being open to change' ($p = 0.025$), 'Subjectivity in science' ($p = 0.014$), and 'The place of creative imagination in science' ($p = 0.019$). These findings show that the experimental group initially performed statistically differently than the control group in these sub-dimensions. No significant difference was observed in other sub-dimensions ($p > 0.05$).

The post-test results showed that the experimental group performed statistically differently in 'Scientific knowledge being open to change' ($p = 0.018$), 'Experiment-based aspect of science' ($p = 0.000$), 'Subjectivity in science' ($p = 0.029$), 'The place of creative imagination in science' ($p = 0.000$), 'Scientific hypotheses, laws and theories' ($p = 0.024$), 'Scientific method' ($p = 0.037$), 'Science and technology' ($p = 0.039$), and 'Science' ($p = 0.022$). This reveals that the experimental group made significant progress in these sub-dimensions depending on the programme or intervention implemented. However, no significant difference was found between the experimental and control groups in the sub-dimensions of 'Social cultural values in science', 'Observations and inferences in science' and 'Scientific models' ($p > 0.05$).

In terms of overall total scores, the experimental group achieved a significant superiority in the post-test ($t = 4.38$, $ss = 0.83$) compared to the control group ($t = 3.94$, $ss = 0.69$) ($p = 0.017$). This result reveals that the experimental group made a positive progress in all sub-dimensions of the Nature of Science Scale in general. The findings indicate that the intervention positively improved the experimental group's perceptions of the nature of science, thus such interventions are educationally effective. However, the fact that there was no significant difference in some sub-dimensions reveals that more specific and targeted programmes should be developed for these areas.

Conclusıon and Recommendatıons

This study aimed to evaluate the effect of NOS activities prepared with technology integration on pre-service science teachers' perceptions and understandings of science. The findings revealed that technology-supported activities were effective in developing pre-service science teachers' awareness of the nature of scientific knowledge and their scientific understanding. It was

determined that the participants in the experimental group showed significant improvement in sub-dimensions such as the openness of scientific knowledge to change, the experiment-based nature of science, the place of creativity in science, and the relationship between scientific method and technology. In addition, a significant superiority was obtained in the experimental group compared to the control group in terms of overall scores. This shows that technology-supported applications are an important tool that supports scientific thinking skills and increases the competences of pre-service teachers in pedagogical processes.

In line with the findings of the study, the following conclusions were reached:

1. Technology-supported activities deepened conceptual and practical understandings of the nature of science. This indicates that the dynamic, creative and social contexts of science were better grasped by pre-service teachers.
2. Integration of Web 2.0 technologies into the educational processes enabled the participants to understand abstract concepts in a more concrete way and to experience what they learnt in a practical way.
3. There was no significant improvement in the control group that received education with traditional methods. This shows that technology integration makes an important contribution to teaching NOS and that traditional methods may be insufficient in this area.
4. The fact that there was no significant difference between the experimental and control groups in some sub-dimensions (social cultural values in science, observations and inferences in science, scientific models) reveals the need for more specific and target-oriented interventions to improve these areas.

Recommendations

1. It is recommended that technology-supported activities should be implemented systematically in courses related to NOS in faculties of education. Such activities will support the development of pre-service teachers not only in terms of knowledge but also in terms of scientific process skills.
2. Active use of Web 2.0 tools should be encouraged at different levels of education, especially in science education. These tools can make teaching processes more interactive, accessible and student-oriented.
3. The fact that no significant difference was found in sub-dimensions such as social and cultural values in science and scientific models shows that these areas should be addressed in more detail. In this direction, it is suggested that educational contents should be enriched for these themes.

4. Special programmes should be developed for pre-service science teachers to adopt technology-supported teaching methods and integrate these methods into pedagogical processes. These programmes should aim to increase both technological and pedagogical knowledge and skills of pre-service science teachers.
5. In order to increase the generalisability of the results of this study and to evaluate the long-term effects of technology-supported applications, it is recommended to conduct long-term research with larger groups of participants.

In conclusion, it can be said that NOS activities supported by technology integration are effective in developing pre-service science teachers' scientific understanding and can be used as an important tool to improve the quality of education. Such innovative approaches have the potential to enhance not only individual learning processes of science education but also social awareness of science.

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RESTRUCTURING PHYSICAL EDUCATION WITHIN THE FRAMEWORK OF GENDER EQUALITY AND INCLUSION IN SPORT PRACTICES

Hediye Yıldırım Ogan[1]

Abstract

The interrelationships of many factors such as gender, class, colour, ethnicity, religious belief, political opinion, culture, physical disability and age are reflected in the macro-level structure of sport and the micro-level practices of physical education. In this context, sport and physical education have a function in which the dominant values in society are reproduced and transmitted from generation to generation.

The aim of this study is to demonstrate that physical education and sport can go beyond traditional practices shaped by gender norms and become a field that promotes equality, includes differences and enables social transformation. Such a transformation requires the re-evaluation and restructuring of educational components such as curriculum, educational environment, teacher approaches, materials used, school administration and parents in a way that overcomes gender discrimination.

In other words, physical education and sporting activities can be reconstructed in a way that supports gender equality and justice. Such a restructuring can enable individuals to freely explore their own bodies, freely express their ideas and freely perform their bodily practices. However, if this approach is not adopted, physical education and sport may not go beyond being a field that hosts various forms of discrimination, especially sexism.

Keywords: Gender inequality, Sports equity, Women athletes, Barriers in sports, Gender-inclusive policies

Introductıon

In the last quarter of the 20th century, as the distinction between biological sex (sex) and gender (gender) became more apparent, education also entered a process of criticism centred on the gender factor. The explanation of personality, intellectual and behavioural differences between men and women based solely on biological reasons has been questioned without ignoring the impact of social factors such as family, culture, society and politics. In this context, the question of whether the education system is a structure that reproduces gender

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discrimination throughout history or a tool that has the potential to transform this discrimination has become a fundamental area of debate (Braun and Clarke, 2019).

The question of whether schools are spaces that facilitate the reproduction of social class, gender, race and dominant ideology has also been frequently raised within the framework of these criticisms. Especially in the contemporary period, efforts to ensure equal opportunities in education have aimed to make visible the reflections of the gender perspective in education. In this context, it can be stated that the primary goal is to ensure access to education for all children, especially girls, and to make this access sustainable. However, beyond the realisation of these goals, the education system needs to be restructured in a way that will enable a broader social transformation. This transformation requires curriculum content to be organised in a way that takes gender equality into account, sexist expressions in textbooks to be eliminated, teachers to gain awareness on this issue and school activities to be planned in an inclusive manner (Capranica et al., 2022).

However, it has been observed that such changes aimed at ensuring gender equality in education are insufficient to fully penetrate the root of the problems. For example, although important steps have been taken, such as the inclusion of girls in education, it is often the case that they end up internalising traditional gender roles defined as ‘docile, submissive, quiet and successful’, whereas boys are labelled as ‘rebellious, brave and extroverted’. Such situations may serve to reinforce the gender-based division of labour within the education system. Therefore, how education should be defined as a structure that does not reinforce gender inequality and which elements it should include or exclude emerges as a critical issue (Wiltshire and Ronkainen, 2021).

Another important point to consider is that efforts to ensure gender equality in education may invisibly reproduce patriarchal codes. For example, the goal of ensuring that girls become literate is of course valuable; however, this process may also lead them to be shaped as introverted and submissive individuals through education. Similarly, the identification of boys with brave and competitive roles leads to a deepening of gender perceptions in the education system. At this point, how phenomena such as sports activities, mathematics, science, engineering and technology being more identified with certain genders and the role of education in the unquestioning acceptance of these processes are among the issues that need to be addressed (Didymus, 2017).

In conclusion, the relationship between gender inequality and the education system cannot be solved only by increasing girls’ access to education. The education system needs to be restructured in a way to promote gender equality and justice. However, such a restructuring will only be possible through the

complete dissolution of gender-based stereotypes in educational environments and the construction of a new, inclusive culture. In this context, studies in the field of physical education and sport reveal that these fields reproduce gender inequality on the one hand, but on the other hand, they have the potential to be transformed for an egalitarian understanding (Bekiari, 2023).

A Gender Perspective on Physical Education and Sport

Does sport have a gender or should it? Is it possible to talk about sports specific to women and men? It is inevitable that this field, which is closely related to biological and social gender, is linked to concepts such as power, power, success, competition, ambition, talent and performance. In this context, the question of whether physical education and sport reinforce patriarchal ideology constitutes an important area of debate (Pereira et al., 2023). At first glance, such a claim may be considered as an unfounded or exaggerated assumption. However, as Canan Koca points out, while encouraging boys to do sports is generally supported by families, girls' association with sports is often limited to the idea that they should preserve their bodies and maintain their feminine qualities. While this situation makes sports a means of self-recognition and overcoming their limits for boys, it can create a structure that hinders self-development for girls (Betzer-Tayar et al., 2017).

In recent years, there has been a significant increase in women's participation in the field of sports with the effect of increased health awareness, legal regulations and women's movements. However, it is difficult to say that this development is realised at the same level in every society or that it always brings positive experiences. For example, the proportion of female athletes in the Olympic Games increased from 14.6 per cent in 1972 to 45 per cent in 2016. Nevertheless, in many societies, including economically developed countries, the fact that sport is still identified with men and that men are more active than women has not changed. Physical education curricula, teacher attitudes and school administrations, as well as course contents and materials used, have a great impact on the maintenance of this perception (Amin et al., 2023).

The qualitative research conducted by Koca and Demirhan in three different schools in Ankara in the 2004-2005 academic year reveals important findings that the field of physical education and sports can be a structure that feeds gender inequality. In the study, individual interviews were conducted with 30 female and 27 male students, three physical education teachers were interviewed, six focus groups were conducted and 47 lesson observations were made. The findings showed that physical education lessons cannot be considered independent of gender norms (Balish et al., 2016).

Questions aimed at understanding students' perceptions of sports and the sports they are interested in reveal the impact of gender on their sport

preferences. For example, a student's answer to the question 'Can a woman play football or weightlifting?' was 'She can, but not as well as men. Gymnastics or volleyball are more suitable. Men are better at boxing and weightlifting' reflects the widespread presupposition that certain sports belong to certain genders. In addition, the idea that sports such as weightlifting, boxing and wrestling disfigure the female body causes female students to stay away from these branches. On the contrary, it was observed that they tended to tend towards sports such as tennis, badminton, volleyball and gymnastics (Mateo-Orcajada et al., 2021).

Another dimension of this situation is the belief that sports is seen as a male-specific field and that female students need to exhibit masculine behaviours in order to take part in this field. In the study, it was observed that female students, who were characterised as 'tomboys', participated in sports such as basketball and football more easily than other female students and did not hesitate when choosing these sports. However, these preferences are often perceived as 'masculinisation' due to social norms and this situation is internalised without being aware of it (Plaza et al., 2017).

In this context, the perception that women must assume the risk of 'masculinisation' in order to be present in sports is not only limited to the field of sports, but also appears in a wide range of fields from politics to professional fields such as engineering. However, what should happen is that women should be able to realise their existence on an ontologically equal ground with men, not by becoming masculinised. Structuring the fields of education and sports in a way that will enable this transformation is of critical importance in ensuring gender equality (Amin et al., 2023).

In conclusion, physical education and sport can be a field that reinforces gender inequality, but it also has the potential to contribute to the transformation of this inequality with the right approaches and policies. However, realising this potential requires questioning social norms and redesigning educational environments with an inclusive approach (Plaza et al., 2017).

Possibilities of Ensuring Gender Equality in Physical Education and Sport

In contemporary debates on the relationship between sport and gender, Dawn Penney argues that physical education teachers need two fundamental changes in both course content and curriculum practice: (i) to move beyond a binarist approach to gender and (ii) to consider gender in relation to age, class, ethnicity, sexuality, cultural and national identity, colour, etc.

The first of these proposals questions the determinism between biological sex and gender. For example, the perception that girls are inferior to boys in sports requiring strength and speed due to their physical structure represents

a perception in which biological differences are shaped by cultural and social patterns. The first step in overcoming such oppositions as strong/weak, active/passive, fast/slow is the acceptance and internalisation of the idea that biological sex is not a destiny. The second suggestion emphasises the concept of 'relationality', which means that individuals can be discriminated against not only because of their gender, but also because of class, ethnic and economic factors. In this context, physical education classes have the potential to transform such discrimination (Kamchibekova, 2022).

Physical Education and Society: Historical and Cultural Perspectives

The historical development of physical education lessons has been shaped as an area where social and cultural codes are transmitted to students. For example, Wright states that boys' participation in sporting activities differed according to social class and ethnicity, with white middle-class boys being encouraged to take leadership roles, while working-class boys were raised to be obedient and disciplined individuals. Similarly, in New Zealand, physical education is focussed on increasing the physical competence of male students in order to build a strong military structure. These examples show that physical education is not only about teaching physical skills, but also about reproducing social norms (Anand, 2024).

A Five-Dimensional Approach to Gender Equality

Monica Parri and Andrea Ceciliani in their study 'Best Practice in P.E. for Gender Equity' propose a five-stage approach to prevent gender discrimination in physical education classes (Uyar et all., 2022):

Design Dimension: It is important to understand students' perceptions of gender, determine their level of awareness and discuss these perceptions in a critical framework. This process allows the student to develop critical thinking skills and discover their own identity.

Methodological Dimension: The use of techniques that will increase the participation of girls and boys in physical activities in lessons contributes to the development of their self-confidence and improvement of their motor skills. Motivational methods, especially for disadvantaged groups, allow students to express their bodies freely.

Curriculum Dimension: A curriculum that is free from content that reproduces sexist discriminations and offers equal opportunities should be created. For example, instead of approaches that recommend football only for boys and fitness activities for girls, content that enables all students to take part in various sports with equal opportunities should be developed.

Relational Dimension: A healthy communication between teachers and students contributes to the development of positive self-perception in students.

Through methods such as narrative techniques, students should be given the opportunity to share their experiences of discrimination and find solutions.

Reflexive Dimension: Adopting a pedagogical approach that questions gender stereotypes can increase the role of physical education in social transformation. This requires teachers not only to act equally, but also to bear the responsibility of making sport free from sexist codes.

The Relationship of Space and Language with Gender

Sports halls, playgrounds and school gardens stand out as spaces where gender relations are reproduced. For example, the fact that a large portion of school gardens are reserved for male-dominated sports such as football may make it difficult for female students to find a place in these spaces. Overcoming such spatial segregation requires adopting an approach to the design of sports spaces that recognises equal access for all genders. Likewise, it is also critical that the language used in sporting events is free of sexist expressions. For example, using gender-neutral language instead of expressions such as 'goal king' or 'play like a man' can make sports more inclusive (Sharma & Singh, 2024).

Results

Physical education and sport is a unique learning area that enables students to explore their physical, emotional, intellectual, academic, social and spiritual aspects with a multidimensional approach. This field offers a structure in which the individual experiences his/her body together with the 'other', exhibits it safely and freely, and thus recognises and defines himself/herself through his/her body. Physical education classes do not only consist of the practice of physical movements, but also create a space of existence for students. However, if this space is not inclusive, the student's self-knowledge process may be hindered by factors such as class, race, gender and cultural discrimination.

Sexist attitudes in sport may prevent students from constructing themselves ontologically. For example, common beliefs such as that female students will look muscular and lose their femininity during sporting activities; that contact sports pose a risk to the female body; that female students are weaker than male students or that they cannot demonstrate their physical performance sufficiently, define sports branches with a gender-based discrimination. Such approaches glorify sport as a field where men display their athletic abilities, while positioning the female body in a fragile and weak opposition. In this way, gender-based power relations glorify one body and degrade the other in sport.

While physical education and sport carry the risk of reproducing sexism, it can also be used as a tool that can eliminate discrimination. For this, it is first of all necessary to ensure the active participation of both genders in the field of sport. However, it is not enough to ensure only quantitative equality;

a qualitative approach should be adopted. Teachers, school management and parents should have gender sensitivity and instil this awareness in students. The following steps can be taken to create an egalitarian sports space:

Inclusive Approach: The interests and needs of female students in sports should be taken into consideration and opportunities should be provided for them to assume leadership roles. Sports branches should be selected in line with the demands of students and practices that prioritise any gender should be avoided.

Avoiding sexist discourses: During the lesson, expressions such as 'throwing like a girl' and 'hitting like a boy' should be avoided, and the materials used should be shared without gender discrimination.

Design of the Educational Environment: Sports fields should not be designed according to the demands of a specific gender, such as a football field. A spatial organisation that all students can access equally should be created.

Social Awareness: In co-operation with parents, it can be ensured that they are aware of gender equality. In this process, the contributions of sports to both physical and psychological development should be emphasised.

Role of Teachers: The teacher is a role model for students. They can contribute to gender equality through their discourses, attitudes and methods. It is important for teachers to review their pedagogical approaches and develop an interdisciplinary perspective to prevent discrimination.

In a physical education class, when the whole class comes together collectively to share a physical experience, it encourages the perception of diversity as a richness. The teacher's avoidance of creating an environment dominated by one gender or group in the classroom ensures that sport becomes an inclusive field. In this context, sport needs to be evaluated not only in its biological and physical but also in its philosophical, sociological, cultural and psychological aspects.

As a result, physical education and sport can become an egalitarian field through anti-discrimination policies and practices. This is possible through the adoption of a perspective that encompasses all differences, rather than an understanding that sees sport as a gender-specific activity. An educational environment where students can freely construct their own identities and grow up as physically and mentally healthy individuals can be supported by an egalitarian attitude of teachers, school administration and parents. In this direction, new studies and research in the field of sport will contribute to the dissemination of policies that strengthen gender equality.

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USE OF WEARABLE TECHNOLOGIES FOR ATHLETES: PERFORMANCE AND DATA-BASED APPROACHES

Hediye Yıldırım Ogan[1]

Abstract

Wearable technologies are increasingly used by athletes and coaches to improve performance and gain a competitive advantage. These devices offer the opportunity to identify areas for improvement and optimise performance by tracking data such as heart rate, sleep quality, movement patterns. This review summarises the results of a literature review to investigate the impact of these technologies on marginal gains in sport performance.

The literature review was conducted through Scopus, PubMed and Web of Science databases and a total of 15 articles were analysed, divided into three main categories:

Location-Based Wearable Devices (LBWs) Track athletes' movements and perform training analyses and injury risk assessment.

Biometric Wearables (BMW) Evaluate fitness status and signs of overtraining by monitoring physiological data such as heart rate, sleep and body temperature.

Performance Wearables (PMW): Optimise training planning by providing performance metrics such as power, speed and distance.

While these devices have the potential to improve athletes' performance, they have limitations such as accuracy, cost and reliability. However, their transformation of sports analytics and athletic monitoring processes demonstrates the value of technological innovations in sports science.

Keywords: Wearable technologies, sport, performance

Introductıon

Today, wearable detectors have an important place in sports science due to their wide range of functions and versatile uses. These devices are used not only to assess and monitor athletes' performance, but also as a valuable support tool for sports development teams. Data based on performance measurement is critical for optimising training programmes and managing athletes' individual development processes more effectively. The concept of 'marginal gains' in the improvement of sport performance has become popular, especially with the work of British cycling coach Dave Brailsford. This philosophy developed by Brailsford suggests that multiple small and incremental improvements that

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affect performance can combine to produce a significant overall improvement (Migliaccio, Padulo ve Russo, 2024). This approach aims to achieve optimised results by focusing on each individual performance component of athletes. Brailsford explained this strategy in the following words: 'It may not seem like much, but if a cyclist can gain just one second per lap, it can make a huge difference to the total'. However, the main challenge in implementing this philosophy is the systematic measurement and management of marginal gains. This is where wearable technologies come into play, facilitating the process of detecting and optimising a multitude of small factors that affect performance. With these devices, athletes' physiological, biomechanical and performance data can be monitored in real time, enabling the development of strategies tailored to individual needs (Seçkin, Ateş ve Seçkin, 2023).

Wearable technologies stand out for their capacity to measure a wide range of parameters in sports performance and health monitoring. Although not all marginal gains can be assessed through these devices (e.g. wheel pressure, cushion density, seat comfort), these technologies are capable of providing comprehensive data in the context of sports performance and sports medicine. However, despite their increasing popularity, many wearable devices lack independent and rigorous scientific testing for accuracy, reliability and validity (Alzahrani ve Ullah, 2024).

Wearable devices, produced in various forms such as wristbands, smartwatches, headbands, rings, etc., are part of a larger family of technologies called consumer technologies (CSTs). CSTs encompass not only smartphones and sensors, but also sophisticated devices for clinical applications. These devices can monitor a wide range of parameters, including movement, biological, physiological and behavioural factors. The data provided provides valuable information to coaches and healthcare teams, enabling them to make informed decisions to optimise athletic performance and develop individual training strategies (Romagnoli et all., 2023).

Initially designed for basic health measurements such as step count and heart rate, wearable devices have gained the capacity to monitor more complex physiological parameters with technological advances. However, there are still questions about the scientific validity and reliability of these advanced measurements. For example, the integration of triaxial accelerometers has significantly increased the ability of these devices to detect movement patterns, sedentary behaviour and sleep patterns. This data is critical not only for general health management, but also for improving athletic performance (Yang, Shi ve Huang, 2024).

The COVID-19 pandemic has accelerated the adoption of wearable technologies, increasing the integration of these devices in sports science and

healthcare. In the context of sports science and training, these devices offer continuous data collection during both active training sessions and recovery periods. Thanks to their non-invasive nature and ease of use, the ability to provide data without requiring constant attendance by athletes or medical staff has increased the attractiveness of these technologies (Fazio et all., 2023).

Although wearable devices are used in a wide range of applications from general health management to professional sports performance, they have been criticised for their accuracy, reliability and validity, especially in the measurement of complex physiological parameters such as cardiac function. This suggests that these technologies should be subjected to more rigorous scientific evaluations. The benefits of wearable devices will remain limited unless they are supported by reliable data (Romagnoli et all., 2023).

Global acceptance of wearable devices is increasing rapidly. Usage has grown significantly in two years, from approximately 600 million devices in 2020 to 1.1 billion in 2022. Projections for the future indicate that these technologies will develop further in the next quarter century, providing cost savings in healthcare and reducing some of the doctor-patient interactions (Yang, Shi ve Huang, 2024).

In order to understand the role of wearable technologies in improving sports performance and to support the effective use of these technologies, this study addresses the following fundamental questions:

1. What is the reliability of data collected from wearable devices?
2. How do wearable technologies affect marginal gains in sport performance?
3. What are the main categories of wearable technologies used in sport?
4. How are these technologies applied to enhance sport performance?
5. What are the limitations of the current state of wearable technologies in sport?

This review aims to address the current state and future potential of wearable technologies in the context of sport science and performance optimisation. By seeking answers to the questions that arise in this context, the study aims to examine the literature in the relevant field from a holistic perspective and to provide a framework that can guide future research.

2. Methodology and Selection Criteria

A comprehensive search of scientific databases such as PubMed, Scopus and Web of Science was carried out by two independent researchers (GM.M. and J.P.) to compile the relevant articles. The collected data were then reviewed and evaluated by two independent reviewers (L.R. and J.P.). Inclusion and exclusion criteria were rigorously defined to ensure the relevance and methodological quality of the studies. In this context, the following criteria were applied:

Inclusion Criteria:

- *Eligibility*: Studies should focus on wearable devices used in a sporting context, particularly devices for monitoring body movements, biophysical parameters and small but significant improvements in athletic performance.

- *Year of Publication*: Priority was given to those published within the last 10 years to ensure the currency of the studies, but early studies of critical importance to the field were also considered if necessary.

- *Study Design*: Randomised controlled trials, systematic reviews and meta-analyses were prioritised. However, observational studies were included when they provided unique insights.

- *Language*: Only articles published in English were considered.

- *Reviewer Approval*: Only peer-reviewed studies were included.

- *Device Orientation*: Studies on wearable devices specifically designed or adapted for sports applications were focused.

Exclusion Criteria:

- Studies focusing only on medical applications of wearable devices.

- Publications that have not been peer-reviewed, e.g. conference abstracts and theses.

- Studies identified as methodologically inadequate.

Document selection was carried out through a three-stage process:

1. Title Screening: Titles were analysed for relevance to the study topic.

2. Abstract Evaluation: Abstracts of potentially suitable studies were reviewed in detail.

3. Full Text Review: The full text of each selected article was analysed in detail.

This process aims to ensure the selection and analytical quality of studies in a systematic and unbiased manner.

Organised Classification of Sports Wearables

With the continuous expansion of the wearable device market, these technologies evolve to adapt to the dynamic needs of consumers. However, this adaptability also poses challenges to establishing definitive classifications. According to the International Electrotechnical Committee (IEC), wearable smart devices are broadly categorised into four main types:

1. Near-Body Electronics: These devices function in close proximity to the body without direct skin contact, such as smart glasses, wireless earbuds, and augmented or virtual reality devices. They utilise short-range sensors and communication technologies to interact with the user and environment, providing contextual information or enhancing sensory experiences.

2. On-Body Electronics: Integrated into clothing or accessories, these devices include smart textiles and wearable jewellery. They employ textile-based sensors or embedded microelectronics to monitor movements and biometric data.

3. In-Body Electronics: Implantable devices designed to be inserted within the body. These devices use biosensors to track internal physiological parameters, such as glucose levels and cardiac rhythms, enabling continuous health monitoring.

4. Electronic Fabrics: Textiles embedded with electronic components and sensors that incorporate conductive threads and flexible circuits. These fabrics are capable of detecting physical and environmental interactions, offering advanced applications in health and activity tracking.

This classification underscores the diverse and multifaceted nature of wearable technologies, reflecting their versatility and innovative potential.

Building upon these four categories, the following list encompasses the range of wearable devices currently employed by athletes:

- **Watches**: Including both basic models and advanced smartwatches.
- **Hearables**: Devices such as earphones, earbuds, and headsets.
- **Smart Clothing**: A variety of garments and accessories, including smart shoes, bras, suits (jackets and trousers), shirts, pants, and socks, equipped with integrated sensors.
- **Smart Jewelry**: Items like bracelets, necklaces, brooches, rings, analog watches, and fitness-oriented jewelry.
- **Head-Mounted Displays (HMDs)**: Devices for augmented reality (AR), virtual reality (VR), and mixed reality (MR) applications.
- **Glasses**: Smart glasses and AR-enabled eyewear.
- **Wearable Cameras**: Compact cameras designed for on-body use.
- **Body Sensors**: Standalone devices for monitoring physiological and biomechanical parameters.
- **Implantable Devices**: Embedded technologies for internal health monitoring.
- **Ingestible Devices**: Swallowable sensors that track internal health metrics.
- **Tattooable Devices**: Skin-applied electronics for biometric data collection.
- **Exoskeletons**: Active and passive wearable frameworks to enhance physical performance or provide rehabilitation support.
- **Location Trackers**: Devices for real-time geolocation tracking.

- **Gesture Control Devices**: Wearables that interpret and respond to physical gestures.

This array of technologies highlights the diverse applications of wearable devices in enhancing athletic performance and monitoring health metrics.

In this study, we have endeavored to categorize wearable devices into distinct groups to establish a comprehensive classification framework that systematically captures their diverse applications in sports. Drawing upon the existing body of literature, we propose a taxonomy that we believe accurately reflects the current utilization of wearable technologies by athletes, providing a robust foundation for future research and practical implementation in the field.

Location-Based Wearables (LBW)

These devices commonly utilize GPS, accelerometers, and gyroscopes to collect detailed performance data. Tracking tools, such as smartphones and GPS-enabled watches, are employed to monitor an athlete's movement and location. They facilitate the measurement of key metrics, including distance, speed, and pace, while also enabling the creation of training maps and the tracking of progress over time. While heart rate data is generally reliable, caution is advised when interpreting metrics such as calorie expenditure, VO_{2max}, heart rate variability, oxygen saturation (O_2), and sleep patterns, as these measures are associated with high error rates (Chingthamu et all., 2023) (Table 1).

Table 1. Location-Based Wearables examples

Existing Product	Application
Garmin Forerunner 245 (Szot, 2024)	A GPS-enabled smartwatch designed to track a range of performance metrics, including distance, speed, pace, and heart rate, while supporting diverse physical activities such as running, cycling, and swimming. Additionally, it offers advanced physiological monitoring features, including heart rate analysis, sleep pattern estimation, stress assessment, and VO_{2max} measurement, providing comprehensive insights into physical fitness and overall well-being.
Polar M430 (Szot, 2024)	A GPS-enabled watch equipped with advanced tracking capabilities, including heart rate monitoring, distance measurement, speed analysis, and pace evaluation. Integrated with a built-in accelerometer, it offers additional features such as step counting, calorie burn estimation, and sleep pattern analysis. The device also includes a suite of training tools, including interval training support, heart rate zone monitoring, and recovery time assessment, making it an invaluable resource for optimizing physical performance and recovery.
APP Nike + Run Club (Lin ve ark., 2020)	This application leverages the phone's GPS functionality to monitor and record the user's running activities. Additionally, it offers personalized coaching guidance to enhance training effectiveness and includes features for seamless integration with social media platforms, enabling users to share their progress and connect with a broader community.
APP Strava (Russell, Potts ve Nelson, 2022)	The device is capable of monitoring heart rate, calculating average and maximum speed, and analyzing speed over specific distances, while also providing an estimation of calories expended. Furthermore, it demonstrates a high degree of validity and reliability, as supported by empirical evidence.
APP MapMyRun (Szot, 2024)	The device offers comprehensive functionality, including distance tracking, GPS-based activity monitoring, heart rate analysis, and audio-guided coaching, providing users with valuable feedback for enhancing performance and achieving fitness goals.

Location-Based Wearables in Sports Disciplines

Wearable devices (LBW) have emerged as valuable tools across various sports, providing athletes with actionable insights to enhance performance and safety:

- **Running**: LBW can monitor running metrics and offer feedback on form, enabling runners to optimize their technique and reduce the risk of injury (Szot, 2024).
- **Cycling**: Cyclists benefit from LBW through features that track distance, speed, and elevation gain. These devices also offer turn-by-turn navigation and safety features, helping athletes train effectively and maintain motivation (Boot et all., 2023).
- **Golf**: In golf, LBW provides real-time feedback on shot performance and aids skill development by tracking key factors such as distance to the hole, green slope, and wind conditions (Tyagi, Singh & Singh, 2022).
- **Skiing**: Skiers can utilize LBW to gain information about terrain and avoid potential hazards. Additionally, these devices track distance traveled and vertical descent, offering critical data for performance analysis (Boot et all., 2023).
- **Swimming**: For pool and open-water swimmers, LBW serves as an essential tool to monitor distance, pace, speed, stroke count, and distance per stroke. They also assist in maintaining optimal body position in the water, contributing to improved technique and efficiency (Kumar et all., 2023).

These capabilities highlight the versatility of LBW in supporting athletes across diverse disciplines, facilitating both performance enhancement and injury prevention.

Biometric Wearables (BMW)

BMW employs a range of advanced sensors, including photoplethysmography (PPG), electrocardiography (ECG), and bioimpedance sensors, to monitor key physiological metrics. These devices are capable of tracking heart rate, respiratory rate, blood pressure, blood glucose levels, and other critical parameters. They also facilitate the assessment of stress levels, recovery status, sleep patterns, and training optimization (Migliaccio et all., 2024).

The growing awareness of the benefits associated with physiological monitoring has driven rapid expansion in this category. However, the scientific reliability of the data provided by these devices remains inconsistent, as not all metrics have been thoroughly validated. Therefore, a cautious and well-informed interpretation of the collected data is strongly recommended (Tyagi, Singh & Singh, 2022) (Table 2).

Table 2. Biometric Wearables examples.

Existing Product	Application
Apple Watch	Equipped with integrated GPS functionality, the device monitors heart rate and various other biometric parameters. Additionally, it provides estimations of sleep duration and energy expenditure, offering valuable insights into overall health and activity levels.
Fitbit Sense	The device features integrated GPS and advanced sensors, including a skin temperature sensor, enabling comprehensive biometric monitoring. It tracks heart rate and provides estimations of sleep quality and stress levels, delivering valuable insights into physiological and well-being metrics.
Oura Ring	The device monitors heart rate and provides estimations of sleep quality and activity levels. It is also employed to measure nocturnal heart rate (HR) and heart rate variability (HRV), offering detailed insights into physiological patterns and recovery states.
Garmin Forerunner 945	The device accurately monitors heart rate and serves as a reliable tool for determining and prescribing appropriate exercise intensity, supporting tailored training regimens and performance optimization.
Samsung Galaxy Watch	The device features built-in GPS and monitors heart rate along with other biometric data. Additionally, it provides heart rate variability (HRV) measurements during sleep, offering comprehensive insights into physiological health and recovery.

Biometric Wearables in Sports Disciplines

Biometric wearable devices (BMW) play a significant role in various sports by offering detailed physiological and performance insights:

- **Running**: BMW devices are capable of continuously monitoring heart rate throughout a run, measuring real-time cardiac drift, and estimating daily caloric expenditure (Boot et all., 2023).
- **Cycling**: These devices not only monitor heart rate but also track additional metrics such as cadence and power output, providing valuable data for training optimization (Szot et all., 2024).
- **Swimming**: BMW technology can effectively measure heart rate in water, along with stroke count and distance per stroke, enabling swimmers to refine their technique and efficiency (Russell, Potts & Nelson, 2022).
- **Golf**: For golfers, BMW devices monitor heart rate alongside swing speed and clubhead speed, supporting improvements in precision and performance (Tyagi, Singh & Singh, 2022).
- **Boxing**: In boxing, BMW devices monitor heart rate while also capturing data on impact, punch force, punch speed, punch time, and recovery, providing a comprehensive analysis of performance (Chinghamu et all., 2023).

Performance Wearables (PMW)

Performance wearables (PMW) are designed to track a range of performance metrics, including power output, force, cadence, speed, and distance, utilizing advanced sensors such as GPS, gyroscopes, and accelerometers. These devices serve multiple purposes: they enhance technique, track an athlete's progress over

time, identify areas requiring improvement, and contribute to injury prevention by detecting potential issues early. Moreover, they optimize training regimens by analyzing the athlete's response to various training stimuli, offering a data-driven approach to performance enhancement (Table 3).

Table 3. Performance Wearables examples.

Existing Product	Application
Stryd	The device, equipped with a foot pod, monitors key metrics such as power output, ground contact time, and stride length. This data serves as a valuable resource for optimizing running economy and enhancing overall efficiency in athletic performance.
Catapult OptimEye	The device captures detailed movement metrics, including speed, acceleration, and distance. This data provides actionable insights for refining technique and enhancing performance in sports such as football, rugby, and cricket.
Wattbike Atom	Utilizing a smart bike, the device monitors critical metrics such as power output, cadence, and heart rate. This data supports the optimization of cycling performance and efficiency, enabling tailored training and performance enhancement.
Polar OH1	The device, worn as a chest strap, monitors heart rate and heart rate variability, providing detailed insights into physiological states. This data is instrumental in evaluating recovery and stress levels, contributing to improved training and well-being management.
Run Scribe	The device measures key running metrics, including distance, pace, step length and frequency, ground contact time, vertical ground reaction force (VGRF), foot angle, and its derivatives [83]. This data provides valuable insights for optimizing running economy, refining technique, and enhancing overall efficiency.

Performance Wearables in Sports Disciplines

Performance wearables have become indispensable tools across various sports disciplines, providing athletes with detailed data and actionable insights to enhance their performance:

- **Running**: These devices monitor running activities by mapping routes and analyzing performance metrics, including pace, calories burned, average and maximum speeds, speed over specific distances, and heart rate. After completing a route, the data are uploaded to associated apps or platforms for comprehensive analysis, identifying strengths and limitations.
- **Cycling**: Performance wearables track essential metrics such as heart rate, cadence, and power output, enabling cyclists to optimize their training and maintain motivation. They also provide turn-by-turn navigation and enhance road safety by offering real-time alerts.
- **Swimming**: Wearables in swimming monitor heart rate, stroke count, and distance per stroke, aiding athletes in improving efficiency and speed. Additionally, they help swimmers maintain pace and direction, particularly in open-water swimming scenarios.

- **Golf**: In golf, performance wearables track heart rate, swing speed, and clubhead speed, supporting athletes in refining their accuracy and scoring. They also deliver real-time feedback on shots, enabling golfers to identify and learn from their mistakes.
- **Basketball**: These devices monitor metrics such as heart rate, distance traveled, and shot accuracy, helping players enhance conditioning, efficiency, and shooting precision. Real-time feedback on plays further aids in tactical improvement and error correction.
- **Soccer**: Performance wearables track various performance indicators, including heart rate, distance covered, metabolic power, acceleration, and sprinting. These metrics assist players in improving conditioning, efficiency, and speed while offering real-time feedback on gameplay to facilitate learning and strategic refinement.

By providing data-driven insights tailored to the specific demands of each sport, performance wearables play a critical role in optimizing athletic performance and supporting skill development.

Result

Wearable technology has significantly transformed the sports domain, revolutionizing training methodologies, performance analysis, and injury prevention strategies. This review categorizes wearable devices into three primary types: location-based wearables (LBW), biometric wearables (BMW), and performance wearables (PMW), each contributing unique insights into different dimensions of athletic performance.

Location-Based Wearables (LBW) have proven highly effective in tracking athletes' movements, providing valuable metrics such as distance, speed, and pace. However, their accuracy is often compromised in environments with GPS signal interference, such as urban areas with tall buildings or dense forests. Moreover, the sampling rate of LBW plays a critical role in ensuring data quality, particularly in sports characterized by rapid changes in direction or speed. Future research should focus on enhancing the precision of LBW in challenging environments and optimizing sampling rates for sport-specific applications.

Biometric Wearables (BMW) provide unparalleled access to physiological data, enabling real-time monitoring of vital parameters such as heart rate, blood glucose levels, and blood pressure. Despite their potential, the accuracy and reliability of these measurements can vary significantly between devices and during intense physical activity. BMW's capacity to detect early indicators of overtraining or fatigue presents a promising avenue, though further research is required to establish robust biomarkers and algorithms for reliable fatigue

detection. Additionally, the continuous monitoring of physiological data raises ethical concerns and data privacy issues that must be addressed alongside technological advancements.

Performance Wearables (PMW) offer detailed insights into athletic techniques and biomechanics, contributing to technique refinement and performance optimization. However, factors such as device placement, calibration, and environmental conditions can affect the accuracy and reliability of data. The integration of PMW data with video analysis and artificial intelligence holds immense potential for comprehensive performance assessments and technique enhancement.

The future of wearable technology in sports is likely to be shaped by emerging innovations such as lab-on-a-chip devices, which facilitate real-time biochemical analysis. Furthermore, integrating wearable devices with virtual and augmented reality systems could revolutionize training and performance analysis. As the field evolves, it is essential to establish standardized protocols for data collection, analysis, and interpretation to ensure consistency and comparability across devices and sports disciplines.

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DIGITALISATION IN CHEMISTRY EDUCATION: REVIEW OF MOBILE LEARNING TOOLS

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SUMMARY

Chemistry education increases the need for innovative teaching methods and technologies as it requires the understanding of abstract concepts. In this context, mobile applications stand out as an effective tool that supports student-centred learning processes. This review study aims to analyse the mobile applications used in chemistry teaching and provide comparisons on the content, design and pedagogical contributions of the applications. In addition, by analysing the effects of these applications on student achievement, the contributions of technology use in education to chemistry learning are discussed in detail.

In the literature, mobile applications used in chemistry teaching are generally categorised as interactive experiment simulations, 3D molecule visualisation tools and problem solving oriented games. For example, virtual laboratory applications such as 'Labster' offer students the opportunity to perform costly or dangerous experiments in a safe environment, while tools such as 'ChemDraw' are aimed at improving molecule modelling skills. Interactive applications have been found to provide higher learning outcomes compared to traditional learning methods, especially with their features that support experimental learning and conceptual understanding.

In this study, the pedagogical contributions of mobile applications are evaluated especially in terms of student motivation, contribution to conceptual understanding and individualised learning opportunities. For example, it was found that applications that support visual learning help to concretise abstract concepts such as chemical bonds and molecular structures. In addition, the flexible access features of mobile applications individualise learning processes by providing time and space independent learning opportunities for students with different learning styles.

The study also compiled the findings of experimental and empirical studies conducted to measure the effects of mobile applications on student achievement. These studies provide findings that mobile application supported education increases students' conceptual understanding levels and improves their motivation to learn. However, it is also emphasised that teachers'

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digital pedagogical competences should be increased in order to use mobile applications effectively.

In conclusion, the effects of mobile applications on chemistry education reveal the potential of technology-supported learning to increase student achievement. However, more comprehensive, long-term studies with large sample groups are needed in this field. This article aims to contribute to the literature by identifying the potential benefits, current limitations and future research areas of mobile applications for chemistry education.

Keywords: Mobile applications, Science education, Student achievement, Educational technologies

INTRODUCTION

The rapidly changing needs of today's societies require the development of systems that will guide individuals and facilitate their adaptation to these changes. Education forms the basis of these systems as a process that continuously develops individuals in accordance with the needs of society. Education, in the most general sense, can be defined as a lifelong development and learning process (Varlık, 2024). The rapid progress of technology has led to significant changes in education as in many fields, and in an age of easy access to information, the progress of individuals towards transforming into an information society has reshaped the understanding of education (İç & Tutak, 2018). This situation has led those interested in the education system to develop approaches that use technology more effectively and facilitate individuals in accessing information (Tutak et al., 2018).

Mobile technology is needed for individuals to be more active in their own learning (Compton et al., 2016). The expectation for mobile learning environments is increasing day by day for people to keep up with the changing social order. The increase in expectations based on mobile learning is thought to shape the educational practices in this field. Until today, many theories and models have been developed to improve the quality of learning and teaching activities in education. The breakthroughs made bring along the search for learning and these searches undoubtedly play a role in the fields of education (Bağır, Önal, & Asiltürk, 20). Technological developments have led to new learning environments by pioneering developments in the field of education. One of these learning environments is mobile learning environments. Mobile learning symbolises learning through mobile devices such as smart phones, mobile computers, tablet PCs and laptops (Ürün Arıcı & Yıldız, 2023). With the introduction of these technological devices into people's lives, societies have become unable to live without these devices. The desire to access information anytime and anywhere has increased and people have started to take an active role in learning activities. According to the active learning approach,

technology should be used as much as possible in learning environments (Özyurt & Aslan, 2023). With mobile technologies, students have succeeded in realising their own active learning anywhere, independent from school. In this context, mobile learning draws attention as an important method that enables individuals to participate in the learning process independently of time and space (Falloon, 2017). It is predicted that mobile learning, which offers flexible learning opportunities to students and learners, is a rapidly developing system and will gain a more widespread place in education in the future.

It can be stated that mobile devices are directly linked to the individual's learning process. This situation allows individuals to adapt to changing conditions and shape their lives accordingly. The increase in the number of mobile devices and the widespread use of these devices make significant contributions to learning processes. However, the need for learners to be constantly on the move and to be independent from spatial or temporal limitations in accessing information is becoming increasingly prominent. On the other hand, epidemics, which have a global impact, have made it compulsory to move education processes to digital platforms. The closure of schools during epidemics has led countries to develop distance education systems and carry out learning processes through digital environments (Önal Karakoyun, 2023). These developments reveal once again that the integration of technology into education has become an inevitable necessity.

The realisation that it is difficult for the education and training system to reach the desired level of quality and to reach contemporary goals with traditional methods has made it necessary to turn to new and innovative searches. Especially the models used in science courses help to concretise abstract concepts and make it easier for learners to understand concepts that they find challenging. Similarly, there is a need for systems that support students to better understand abstract concepts. Based on this need, various researches and studies have been initiated to support education with technology. The production of new generation mobile devices, especially smartphones and tablets, and the rapid adoption and widespread use of these devices by the society have paved the way for the emergence and development of the concept of mobile learning (m-learning) (Ly, 2022). Mobile learning draws attention as an effective method that supports the innovative use of technology in educational processes.

Mobile learning refers to the use of mobile technologies alone or in combination with other information and communication technologies to provide individuals with the opportunity to learn anytime and anywhere. This concept has emerged as a result of individuals' intensive use of technology. In a general definition, mobile learning is an interaction process that emerged with the combination of mobile computing and e-learning. This process provides

individuals with a learning experience that allows them to communicate with other learners regardless of space and time, to benefit from up-to-date services and to access constantly updated information (Ekici & Erdem, 2020). The increasing use of technology and the continuous updating of information have led to the importance of concepts such as distance education, e-learning and mobile learning (m-learning). Among these approaches, the use of mobile devices that lead to radical changes in access to information has a remarkable place. In a period when people are racing against time in the modern world, mobile technologies go beyond being only a communication tool and provide easy access to unlimited information in the field of education at any time and any place thanks to the applications developed. The widespread use of mobile devices and the popularity of digital games, especially among young people, have led educators to develop educational mobile applications and games that utilise mobile device technology and games (Tavares, Vieira, & Pedro, 2021). While these developments enable students to interact with information more effectively, they also contribute to learning processes by supporting the use of technology for educational purposes.

In this study, it is aimed to determine how mobile learning-based applications affect students' attitudes towards mobile learning, their motivation, attitudes and academic achievement in science course. The research aims to comprehensively examine the effects of the integration of mobile learning technologies into educational processes on student behaviours and learning outcomes.

Research Questions

Within the scope of this research, answers to the following questions were sought:

1. Which research methods, sample selection criteria and data collection tools are used to determine the effects of mobile learning applications in science education?

2. How do studies reveal the effects of mobile learning applications on science education processes and in which dimensions are these effects evaluated?

3. What are the suggested future research topics for determining the effects of mobile learning applications in science education?

Material and Method

This study aims to reveal the types of research on mobile learning applications in science education and the connections between them, and to guide future research in this way. In this direction, document analysis method was used (Minner et al., 2010; Baran & Bilici, 2015). Document analysis is a systematic method that covers the processes of scanning, finding, examining and evaluating existing sources within the framework of a specific purpose

(Karasar, 2005). This method was carried out in four basic stages: source screening, determination of selection criteria, screening process and data analysis (Karaçam, 2013; Baran & Bilici, 2015). These stages of document analysis are discussed in detail below.

Screening Method and Determination of Selection Criteria

In this study, document analysis method was used. In the first stage of the study, certain criteria and keywords were defined to examine mobile learning applications in science education. Articles published in peer-reviewed journals or open to international access between 2010 and 2023 were included in the scope of the study. These studies have been carried out since the early 2000s, especially to examine the effects of mobile learning applications on educational processes. In order to reach the sources related to the research topic, national and international publications were searched by using both Turkish and English keywords. In this context, terms such as 'mobile learning', 'mobile learning in science education' and 'mobile technologies' were preferred in Turkish and keywords such as 'mobile learning', 'mobile learning in science education' and 'mobile technologies' were preferred in English. Thus, access to current and comprehensive studies in the literature on the subject was provided.

Screening Process

In this study, keywords suitable for the research topic were determined in order to access articles on mobile learning. A comprehensive search was carried out in ISI Web of Science, EBSCOHost, Science Direct, ERIC databases and Google Scholar search engines. The studies obtained as a result of the search were examined in detail in terms of title and content, and those that were not directly related to the research topic were excluded from the scope of the research. At the end of this process, a total of 8 articles were selected to be included in the research. The bibliographies of the included articles were also examined to identify theses or articles that may have been overlooked during the search. However, no additional studies were found by this method. The fact that the studies included in the scope of the research were conducted relatively recently and that the research topic was located at the intersection of science, educational technology and education were considered among the factors limiting the studies. In this context, the limited number of selected publications is seen as an expected situation due to the nature of the research topic.

Analysis Process

In this study, during the content analysis process of the articles, categories such as research topic, method used, study group, data collection tools, data analysis techniques, findings and main conclusions were taken into consideration. With this approach, it was aimed to evaluate the studies within the scope of the research in a systematic way.

CONCLUSION AND DISCUSSION

In this study, the articles selected as a result of the search in accordance with the criteria detailed in the methodology section were analysed in terms of research topic, method used, study group, data collection tools, data analysis techniques, findings and main conclusions.

Crompton et al. (2016) understood the rapidly increasing use of mobile learning in education and systematically examined the research trends in this field. In the study, scientific studies on mobile learning published since 2000 were comprehensively analysed and synthesised. In the research, it was determined that the focus was mostly on the design of mobile learning systems, the evaluation of the effects of these designs and the examination of affective dimensions in the mobile learning process were other priority issues. It was determined that most of the studies were carried out in the field of life sciences and in informal learning environments with primary school students aged 5-11 years. It has been observed that mobile devices are used effectively in informal learning environments where connections with the real world can be easily established. The use of various methods in the studies provided a multifaceted research perspective on mobile learning. The findings reveal the importance of investigating how these technologies can be used more effectively in all areas and levels of science education with the increasing use of mobile learning in education. In this context, the need to increase the capacity of teachers to integrate mobile technologies in science learning processes is emphasised.

Burden and Kearney (2016) adopted scenario planning as a methodological approach and tool for the use of mobile technologies in the context of science education. The theme of the research is to encourage science educators to adapt the way they use mobile technologies to different futures and to help them rethink pedagogical practices in this context. The ‘futures’ discussed in the research are not presented as precise predictions or forecasts, but as intellectual tools to stimulate deeper discussion and reflection on the role of mobile technologies in science education. Drawing on the relevant literature and empirical data collected, the research explored four alternative future scenarios for science education in a mobile world. Particular focus was placed on networked collaboration and student autonomy. Scenario planning technique was used as the research method and data from student and educator experiences were analysed. The analysis of the data focussed on assessing how mobile technologies can be used to overcome the boundaries between physical and virtual environments and its impact on pedagogical approaches. The findings revealed that the concept of ‘seamless learning’ enables students to connect in-school and out-of-school activities with the help of mobile technologies and that this process is an important factor in realising the potential of contextual

participatory learning in science education. The research showed that the integration of mobile technologies into existing pedagogical practices can contribute to educators‘ restructuring of their teaching approaches and increase students’ active engagement in science education. As a main conclusion, it is emphasised that student-centred and contextual learning processes can be strengthened if mobile technologies are used correctly.

Tavares, Vieira, and Pedro (2021) reported in their research a part of a larger study on the development of a mobile application for science education at primary school level. The main theme of the research is to examine how innovative learning approaches can be designed to promote the use of technology, especially educational software, in science education in a structured way. The research aims to reveal how the interaction between students and a mobile application developed for science education supports the development of students’ scientific competences and self-regulated learning skills. In the research, a learning model was designed by combining theoretical approaches such as Universal Design Learning Principles, Inquiry-Based Science Education and BSCS 5E Teaching Model. This model includes the stages of Engagement, Exploration, Explanation, Elaboration and Evaluation. A participatory and user-oriented methodology was adopted and data were collected from primary school teachers (n = 118) through a literature review and a questionnaire. The data were analysed to assess the appropriateness of the designed learning approach according to Nieveen’s criteria for high quality educational interventions. Teachers’ opinions emphasised two main effects of the proposed mobile application: (i) its potential to provide a comprehensive and practical science education experience; (ii) its capacity to develop students’ scientific competences and self-regulated learning skills. The main findings of the study revealed teachers’ positive views that such a mobile application could be an important innovative tool for science education. As a result, this study aims to contribute to the design of innovative learning approaches in science education and to provide an important reference for researchers and educators by showing that this model can be extended to other educational software.

In their research, Ekici and Erdem (2020) examine the effect of mobile scientific inquiry on the acquisition of Science Process Skills (SPS), one of the main objectives of science education. The main topic of the research is how to support the development of SPS of pre-service teachers through their participation in scientific inquiry activities through a mobile application. The study was conducted with a mixed-method design in which quantitative and qualitative data collection methods were used together. In the study, a mobile application developed by the researchers was used for the participants to use for eight weeks. The study group consisted of 94 pre-service teachers. Data were collected through the Scientific Process Skills Test, semi-structured interviews

and reflective diaries. The analysis of quantitative data revealed that mobile scientific inquiry significantly and positively improved pre-service teachers' science process skills. The analysis of qualitative data supported this positive change, and it was seen that the participants presented positive reflections on the skills they gained during the application process. The main findings of the study show that the mobile scientific inquiry approach is an effective method in the development of students' scientific process skills. In addition, the participants had the opportunity to apply scientific inquiry methods in this process and this enriched their learning experiences. As a result, the study reveals that the integration of mobile scientific inquiry into science education processes is an effective tool to support students' acquisition of scientific skills and provides guidance for future studies on this subject.

Tümkaya and Hürriyetoğlu (2022) aimed to determine the trends of studies conducted and published using mobile applications in the field of mathematics and science between 2011 and 2021. In the study, the related studies were searched through ULAKBIM, ProQuest, Turkish Education Index, ERIC, Google Scholar, Academia.edu databases and National Thesis Centre. The obtained studies were examined by descriptive content analysis method and categories such as type, publication year, publication language, index information, application type, field of study, research method and design, sample type, sample size, measurement tools, data analysis techniques and results were analysed. Within the scope of the research, a total of 29 scientific studies were reached; 25 of these were articles, 3 were master's theses and 1 was a doctoral thesis. Of these studies, 16 were conducted jointly in the fields of mathematics, 9 in the fields of science, and 4 in the fields of mathematics and science. The findings revealed that the studies using mobile applications were intensified especially in 2019 and the language of publication was predominantly English. In terms of research methods, quantitative methods were mostly preferred.

Akgün and Üstün (2023) aimed to examine the academic articles in which augmented reality and mobile learning and augmented reality and mobile application variables were discussed together in the field of education in the last five years (2018-May 2022) and to reveal the results obtained from these studies in detail. Within the scope of the research, 65 studies were identified as a result of the searches in the Web of Science database and these studies were analysed according to the criteria determined. The research was conducted by content analysis method and the studies were evaluated within the framework of categories such as year, field of education, keywords, journal, research method, data collection tools, data analysis techniques, level and number of participants. The data were analysed using descriptive statistics, t-test and content analysis techniques. The study group consisted mostly of university

students, and the number of participants generally ranged between 31-50 and 51-100. Questionnaire was most frequently used as a data collection tool. The findings of the study revealed that the most articles in the relevant field between 2018 and 2022 were published in 2020 and these studies were mostly conducted in Taiwan. It was determined that the studies mostly focused on the field of science, and the journal 'Interactive Learning Environments' was the most preferred publication platform. Quantitative methods were mainly used in the studies and it was emphasised that mobile learning with augmented reality facilitates the acquisition of knowledge in learning processes, increases students' interest in learning and strengthens motivation. As a result, the integration of mobile augmented reality applications into education enriches students' learning experiences and shows that the interest in the use of interactive technologies in education is increasing. This study presents the current trends in research on mobile augmented reality and mobile learning and provides a guiding source for future studies in this field.

Perry and Klopfer (2014) examined the potential benefits and challenges of integrating games for learning into educational environments. The main topic of the research is to investigate how ubiquitous games developed for mobile devices provide opportunities for students to contribute to their learning processes outside of school and for teachers to reflect on the curricula linked to these games in classroom activities. Within the scope of the study, four biology-themed UbiqGames and corresponding curricula were developed over a period of two years. The research focused on analysing game play patterns and students' knowledge gains. The study group consisted of male and female students, and it was determined that both groups actively participated in the games. In-game interaction recordings and a knowledge test were used as data collection tools. The data were evaluated through analyses linking students' content knowledge gains to game design features (e.g., simulation feedback and depth of content). The findings showed that students who played biology-themed UbiqGames increased their content knowledge levels. The correlation between the design features of the games and learning outcomes revealed that especially simulation-based feedback and in-depth content presentation positively affected students' learning processes. However, it was emphasised that further research is needed to determine which dimensions of these features contribute most to learning. Although the research points to the potential of integrating casual learning games into the educational curriculum to enrich students' learning experiences, more design-based studies are needed in this field. This study opens new research avenues for the effective implementation of game-based learning approaches.

COMMENTS AND SUGGESTIONS

The rapid development of mobile technologies in recent years has led to significant changes in the field of education. Especially science education is becoming more dynamic and individualised than traditional methods thanks to the flexibility and interactive learning opportunities offered by mobile learning applications. Mobile learning makes it possible for students to access information independently from time and space and to develop their conceptual and practical skills in the field of science. In this context, research on the effects of mobile learning applications in science education both analyses the current use of these technologies and provides road maps for future studies. This study aims to make a comprehensive evaluation of the role of mobile learning in science education processes in terms of research methods, effects and future research suggestions.

In the literature, research methods such as mixed-method, quantitative research and quasi-experimental design are generally preferred to determine the effect of mobile learning applications in science education. Most studies are conducted with quasi-experimental design using experimental and control groups to assess students' knowledge levels, motivation and science process skills. Sample selection criteria are usually based on characteristics such as a specific age group, education level or mobile device usage skills. Sample groups frequently consist of middle school, high school and university students. Among the data collection tools, questionnaires, achievement tests, semi-structured interviews, reflective diaries and observation forms are commonly used. These tools are used to assess the effects of mobile applications on science education from both qualitative and quantitative perspectives.

Research has addressed the effects of mobile learning applications on science education processes in a multidimensional way. The findings reveal the positive effects of mobile learning applications such as developing science process skills, supporting conceptual learning, and increasing students' motivation. In addition, mobile learning applications were reported to improve students' skills such as critical thinking, collaborative learning and adapting to individual learning speeds. In the studies, it is stated that factors such as application design and content depth are directly effective on learning outcomes. However, limitations such as internet infrastructure, teacher competence and application accessibility are also effective in the use of mobile learning applications. Research generally emphasises the need for better designed content and teacher support to increase the educational benefits of mobile learning.

It is suggested that future research should address the following issues:

- Inclusive and individualised learning experiences: How mobile applications can be tailored to different learning styles and individual needs should be explored.

- Long-term effects: The lasting effects of mobile learning applications on students' science knowledge should be examined through long-term longitudinal studies.

- Teachers' technology integration competences: How teachers can integrate mobile learning applications into the classroom environment and how they can be supported in this regard should be investigated.

- Applications in various science subjects: Studies comparing the effects of mobile learning in different science disciplines (biology, physics, chemistry) should be conducted.

- Interactive and collaborative learning processes: How to encourage collaboration among students through mobile learning and its impact on learning outcomes should be investigated.

- Digital inequality: By examining the effects of mobile learning applications on different socioeconomic groups, strategies to reduce digital inequality can be developed.

In conclusion, the effects of mobile learning applications in science education should be evaluated in a broad framework and future studies should provide guidance to integrate technology into educational processes more efficiently. In particular, more research is needed to solve the content development processes and infrastructure problems of the applications. These efforts will contribute to a more effective and inclusive restructuring of science education processes.

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ENVIRONMENTAL EFFECTS OF PLASTICS AND THEIR PLACE IN CHEMISTRY EDUCATION

Erol Asıltürk[1]

SUMMARY

Environment has been handled as an important interdisciplinary subject in the context of science and chemistry education from past to present. Humanity's need to maintain a high standard of living leads to an increase in consumption habits, which in turn leads to a rapid increase in the amount of waste and environmental pollution. In this context, plastic materials, which are widely used in daily life and in different sectors of industry, have an indispensable place especially in industries such as packaging, construction, automotive, electrical and electronics. However, at the end of the service life of plastics, it is seen that they generate a large amount of waste and only a limited portion of them can be re-evaluated by recycling. This situation makes the recovery of plastic wastes a critical issue in terms of both the efficient use of economic resources and environmental sustainability. In the context of chemistry education, transferring the environmental effects of plastic wastes and recycling processes to students stands out as an important learning goal in terms of gaining sustainability awareness and developing solutions to environmental problems. Therefore, the integration of waste management and recycling processes into chemistry education requires an approach that aims not only to transfer theoretical knowledge but also to raise environmentally conscious individuals.

In this study, research on how the environmental effects of plastics are used in science and chemistry education was reviewed. Articles on the subject were obtained from databases and analysed. The subject, method, study group, data collection tool, data collection tool, analysis methods, use of cloud computing technology and the results obtained were examined by document analysis method.

In conclusion, addressing the environmental impacts of plastic waste from a chemical perspective requires both the development of existing recycling methods and the implementation of innovative solutions. Chemical-based approaches such as catalytic chemical recycling, production of biodegradable polymers and upcycling offer promising strategies to reduce the environmental impacts of plastics. However, the chemical interactions of plastic wastes that cause environmental damage, especially in aquatic ecosystems, need to be

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examined in more detail. These innovative methods offered by chemical science will support the transition from a linear utilisation model of plastics to a circular economic model and provide an important basis for a sustainable future.

Keywords: Environmental pollution, Plastic waste, Recycling, Sustainability, Science Education

INTRODUCTION

The use of plastics is increasing day by day in parallel with the increasing population and technological developments and is gaining a wider place in daily life. While the rise in living standards has led individuals to consume more goods to meet their daily needs, advances in technology have made it possible to produce many products from plastics (Bucknall, 2020). Plastics that become fluid when heated and can be easily shaped are called thermoplastics. Thermoplastics can be easily processed and shaped due to their low hardness and strength properties. Plastic materials used in daily life are softened at a certain temperature and produced in the desired form by moulding method. These materials have the ability to be melted again after the initial moulding process and transformed into different products, which offers an important advantage in terms of recyclability (Coates and Getzler, 2020).

The main reason for the rapid expansion of the usage areas of plastics is that they can be processed more easily compared to other materials. In addition to the ease of processing, the increase in the use of plastic raw material products provides positive indicators about the level of development of countries. Plastics, which are the basic building materials of many products frequently used in daily life, have an important place in a wide range of areas such as construction, packaging, electronics and automotive. However, the disposal of plastics after use becomes an environmental problem and large piles of waste are generated in proportion to the amount of plastic used. Plastics, which cease to be a useful material after use and become harmful, become a part of the damages caused to nature by human hands. The realisation of the extent of the damage caused by plastic wastes to the environment has brought along the need for protection from the negative effects of these wastes. In this context, it has become necessary to ensure the recycling of plastics, which are widely preferred for their low-cost and easy-to-process properties. Thanks to recycling efforts, plastic wastes that harm the environment can be reused, minimising these damages and contributing to a sustainable environment (Situmorang, Liang, & Chang, 2020).

With the widespread awareness that recycling plastics can reduce environmental damage, many countries provide descriptive information on plastic products, indicating the type of plastic used. This approach makes the recycling process of plastic waste faster and easier. However, the environmental

impacts of the methods commonly used for the recycling of plastic waste remain controversial. Two main methods are generally favoured for recycling: landfilling and incineration. Although incineration is used to obtain energy, it is not considered a fully sustainable solution in terms of its environmental impacts. During incineration, toxic components produced by the combustion of plastics are released into the air, causing serious environmental and health problems. Similarly, landfilling is a process in which plastic wastes are covered with soil. However, in this method, precipitation and groundwater can pass through the layers where the wastes are located and cause contamination of other surrounding areas. In addition, it is not fully predictable what kind of damage plastics may cause to the environment during their natural degradation processes under the soil. Considering both the environmental impacts and economic costs of these methods, it is seen that they do not offer fully sustainable solutions for the recycling of plastic wastes. Therefore, there is a need to develop more effective and environmentally friendly methods in recycling processes. It is aimed not only to reduce environmental damages by recycling plastic wastes, but also to contribute positively to the economy. Accordingly, the research and implementation of innovative and sustainable methods is of great importance for the future of recycling (Podgórski et al., 2020).

In reducing the environmental damage of plastic wastes, especially the conversion of plastics such as polyethylene (PE) into fuel or different chemicals in the recycling process stands out as an important approach. In addition to reducing the environmental impact of plastic wastes, this transformation also enables the creation of economic value. Among the products that can be obtained from plastic waste through thermal decomposition are various chemicals such as alpha-olefins, surfactants, lubricating oils. In order to recycle plastic waste in a harmless and economical way, hydrogenation and pyrolysis, one of the basic processes of chemical recycling, are generally preferred (Singh et al., 2019).

This research aims to address the environmental impacts of plastics and explain the key role chemistry plays in minimising these impacts. The development of chemical recycling technologies has the potential to provide both a sustainable environment and economic gains by transforming the environmentally problematic nature of plastic waste. In this context, studies on effective recycling methods of plastics make an important contribution to the balance between environment and economy.

Research Questions

Within the scope of this review study, answers to the following questions were sought:

1. How are the environmental impacts of plastic wastes addressed in the literature and which methods are suggested to minimise these impacts?

2. What are the effectiveness of chemical methods (e.g. pyrolysis and hydrogenation) used in the recycling processes of plastic wastes in terms of reducing environmental damages and providing economic gains?

3. What are the suggested research topics to be addressed in the future to minimise the environmental impacts of plastic wastes and to develop sustainable recycling technologies?

Material and Method

This study aims to reveal the types of studies that address the effects of plastic wastes on the environment from a chemical perspective and the relationships between them, thus aiming to guide future studies in this field. For this purpose, document analysis method was used (Minner et al., 2010; Baran & Bilici, 2015). Document analysis is a method that includes the processes of systematic scanning, finding, examining and evaluating existing sources for a specific purpose (Karasar, 2005).

This method was carried out in four basic stages: source screening, determination of selection criteria, screening process and data analysis (Karaçam, 2013; Baran & Bilici, 2015). Each stage was carefully planned and implemented to support the scope and purpose of the research. Detailed explanations of these stages of document analysis are presented below.

Determination of Screening Method and Selection Criteria

In this study, document analysis method was used. In the first stage of the study, certain criteria and keywords were defined in order to examine the impact of plastic wastes on the environment from a chemical point of view. The scope of the study included articles published in refereed journals or open to international access between 2010 and 2023. These studies have been carried out since the early 2000s to examine the impact of plastic wastes on the environment, especially from a chemical perspective. In order to reach the sources related to the research topic, national and international publications were scanned by using both Turkish and English keywords.

Screening Process

In this study, keywords suitable for the research topic were determined in order to reach the articles on the impact of plastic wastes on the environment. A comprehensive search was carried out in ISI Web of Science, EBSCOHost, Science Direct, ERIC databases and Google Scholar search engines through the determined keywords. The studies obtained as a result of the search were examined in detail in terms of title and content, and those that were not directly related to the research topic were excluded from the scope of the research. At the end of this process, a total of 4 articles were selected to be included in the research. The bibliographies of the included articles were also examined to

identify articles that may have been overlooked during the search. However, no additional study was found with this method.

Analysis Process

In this study, during the content analysis process of the articles, categories such as research topic, method used, study group, data collection tools, data analysis techniques, findings and main conclusions were taken into consideration. With this approach, it was aimed to evaluate the studies within the scope of the research in a systematic way.

CONCLUSION AND DISCUSSION

In this study, the articles selected as a result of the search in accordance with the criteria detailed in the method section were analysed in terms of research topic, method used, study group, data collection tools, data analysis techniques, findings and main results.

Belmokaddem et al. (2020) aimed to reduce environmental impacts and contribute to sustainable development by recycling plastic wastes and using them as aggregates in the production of building materials. The main topic of the study was to investigate the effects of replacing natural aggregates with plastic wastes at certain ratios on the thermal, mechanical and acoustic properties of concrete. The research focused on the use of three different plastic wastes based on polypropylene (PP), high density polyethylene (HDPE) and polyvinyl chloride (PVC) in different proportions (25%, 50% and 75% of natural aggregates) in concrete formulation. In the experimental study, the effects of plastic wastes as aggregates on various properties of concrete were comprehensively evaluated. The morphological, thermo-mechanical and acoustic properties of the aggregates and their environmental effects were analysed. Density measurements, dynamic elastic modulus analysis, thermal conductivity tests and acoustic insulation measurements were used as data collection tools. The data were analysed using comparative analysis techniques. The results showed that plastic wastes reduced the density of concrete, resulting in a lighter construction material. Concrete with 75% PE aggregates had a lower dynamic elastic modulus and a more flexible composite material was obtained. In addition, the thermal conductivity value of concrete containing 75% PVC aggregate decreased to 0.61 W/m-K, improving the insulation properties of concrete. The use of plastic wastes in concrete increased the acoustic insulation capacity of the material, resulting in the development of a composite building material with interesting properties. As a result, the use of plastic waste in concrete formulation stands out as a promising method to reduce environmental pollution and mitigate the damage caused by plastic waste to the environment. This approach offers an effective solution to combat global warming and

pollution, while contributing to the development of environmentally friendly and sustainable construction materials.

Trotter et al. (2019) examines the indirect effects of plastic waste on chemical communication and organisms in aquatic ecosystems. The main topic of the research is to determine how plastic wastes accumulating in the environment affect chemical communication processes that are critical for the survival of aquatic organisms. In particular, this study on the planktonic water flea Daphnia longicephala aims to evaluate the effects of plastic waste on the defence mechanisms of this organism. In the study, the interaction of plastic wastes containing high-density polyethylene (HDPE) and polyethylene terephthalate (PET) with kairomones regulating the perception of predation risk was investigated. In the study, Daphnia longicephala samples were used as the study group. In the experimental design, water fleas were kept in an environment combined with kairomones (predation signals secreted by Notonecta glauca) and plastic waste. During data collection, measures representing defence mechanisms such as body length, head crest width and time to first birth were evaluated. The data were analysed using comparative analysis methods. Results revealed that Daphnia longicephala showed a decrease in all defence traits (body length, head crest width and time to first birth) in the environment where kairomones and plastic waste coexisted. However, no effect of plastic waste on defence traits was observed in the absence of kairomones. This suggests that plastic waste disrupts chemical communication processes, preventing organisms from developing defence mechanisms appropriate to predation risk. Such misperceptions can have far-reaching consequences at the ecological level and disrupt the dynamics between trophic levels. In conclusion, this research reveals that plastic waste can have serious indirect impacts on aquatic ecosystems not only through physical but also chemical interactions. These findings make an important contribution to understanding the effects of plastic pollution on the survival strategies of aquatic organisms and highlight the need for larger-scale measures to combat plastic pollution.

Situmorang, Liang, and Changs (2020) aimed to examine the impact of university-level environmental education on increasing students' environmental awareness, especially when addressing issues related to plastic waste. The main topic of the study was to determine the differences between the knowledge and behaviour levels of students studying in environmental sciences and social sciences departments about plastic waste and to evaluate the relationship between knowledge and behaviour. The study was conducted on 98 students studying at National Chung Hsing University in Taiwan. A questionnaire was used as a data collection tool, and the negative effects of plastic waste and behaviours to reduce the use of plastic were evaluated. The data obtained were analysed by t-test and Chi-square analysis to analyse the differences in

knowledge and behaviour levels, and Kendall's rank correlation analysis to examine the relationship between knowledge and behaviour. The findings showed that the departments in which the students studied led to significant differences in their knowledge levels about the negative effects of plastic wastes. It was determined that environmental sciences students had a higher level of knowledge on this subject. Similarly, it was found that the behaviours of environmental sciences students towards reducing the use of plastics were more positive compared to social sciences students. These behaviours were observed through concrete steps in daily life such as avoiding buying products with plastic packaging, preparing shopping bags, reusing plastic bags, carrying their own lunch boxes and avoiding single-use plastic packaging. In addition, a positive relationship was found between environmental knowledge about plastic waste and behaviours towards reducing plastic use. In conclusion, this study reveals that environmental education directly contributes to students' plastic waste awareness and behaviours. The finding that environmental sciences students exhibit higher knowledge and positive behaviours emphasises that environmental education should be given importance in a wider student population. This study shows that the dissemination of environmental education in universities can contribute to long-term strategies for solving plastic waste problems.

Worch and Dove (2020) examined the role of plastics in the current global materials economy and the critical role chemistry plays in the transition to a more sustainable plastics industry. The main topic of the research is the evaluation of approaches such as chemical methods developed to reduce the environmental impact of plastics, new recycling technologies and the development of biodegradable plastics. Although plastics are a material that transforms many industries, the fact that they are generally seen as disposable products has increased environmental problems and has revealed the need to develop more innovative and circular methods to solve these problems. In addition to the existing recycling methods, the research focussed on innovative technologies such as catalytic chemical recycling and upcycling, which aim to transform plastic waste into more valuable products. During the data collection process, existing studies in the literature were systematically analysed and information on new materials and recycling technologies used in the plastics industry was compiled. The data was analysed through a comparative approach aiming to assess the potential of these technologies on reducing environmental impacts and integrating plastics into a circular economy. The research findings reveal that methods such as the development of biodegradable synthetic plastics and the use of renewable raw materials have significant potential as alternatives to existing petroleum-based plastics. Furthermore, new technologies such as catalytic chemical recycling and upcycling have shown promise in reducing

the environmental impact of plastic waste and transforming waste into high value products. These technologies support the transition of the materials economy from a linear to a circular model, both alleviating the current plastic waste problem and contributing to future waste management strategies. As a result, it is emphasised that chemistry has a critical role in helping the plastics industry achieve its sustainability goals. The research shows that the adoption of innovative approaches in the management of plastic waste and the development of recycling technologies will contribute to the solution of environmental crises and make the global material economy more sustainable.

COMMENTS AND SUGGESTIONS

Research on reducing the environmental impact of plastic waste and creating a sustainable economy offers innovative solutions in many areas from the use of plastics to recycling. These studies assess the direct and indirect impacts of plastic waste on the environment and investigate how recycling technologies and education programmes can minimise these impacts. The common point that draws attention in the studies is that plastic wastes are addressed not only with their environmental damages but also with their contribution to sustainable material economy.

Studies reveal that innovative technologies used in the recycling of plastics (e.g. chemical recycling, upcycling, development of biodegradable plastics) offer promising solutions in both environmental and economic terms. However, it is emphasised that further research is needed to address the technical and economic barriers to the diffusion of these technologies. Moreover, not only the physical aspects of the environmental impacts of plastic wastes but also their chemical impacts on aquatic ecosystems are becoming increasingly important. This situation reveals the necessity of a multidimensional approach in environmental analyses.

Research in the field of education shows that environmental education plays an important role in increasing plastic waste awareness. The strong relationship between environmental knowledge and behaviour emphasises the importance of individual and social awareness in reducing the impacts of plastic waste. More emphasis on environmental education in universities may contribute to the development of long-term solution strategies for plastic waste problems.

Recommendations

1. Dissemination of Technological Innovations: Policies and incentive mechanisms should be developed to reduce economic and technical barriers for the wider application of chemical and biotechnological methods used in the recycling of plastic waste.

2. Multidimensional Environmental Analysis: Comprehensive analyses covering not only physical but also chemical and ecological aspects of the

environmental impacts of plastic wastes should be conducted. These analyses are critical for the protection of sensitive environments such as aquatic ecosystems.

3. Education and Awareness: Environmental education programmes should be expanded to encourage individual behavioural change to address plastic waste issues, and curricula should include practical content to reduce plastic use.

4. Policy and Regulations: Policies that encourage the use of biodegradable plastics for the management of plastic waste should be developed and regulations that support recycling processes should be made.

5. Research Collaborations: By encouraging interdisciplinary collaborations, global research networks that produce innovative solutions for recycling plastic waste and reducing its environmental impact should be established.

In conclusion, while developing solutions to the plastic waste problem, adopting environmentally friendly technologies, raising awareness through education and supporting sustainable economy models should be considered as basic strategies. These approaches are critical to reduce the negative impacts of plastics on the environment and to create a circular material economy.

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THE CONCEPT OF DIGITAL TEACHING AND SCIENCE TEACHERS' PERCEPTIONS OF DIGITAL TEACHING

Gülen Önal Karakoyun[1]

SUMMARY

This study aims to examine science teachers' perceptions of digital teaching and the effects of these perceptions on educational processes by addressing the concept of digital teaching. In our age of rapid digital transformation, the teaching profession is also reshaped by technology and digital teaching emerges as a competence area that requires the integration of pedagogical skills with technology. Digital teaching involves the effective use of technological tools and resources, digital content production, digital literacy skills, and effective communication with students on virtual platforms.

This study systematically reviews the research conducted to determine science teachers' perceptions of digital teaching and evaluates the contributions of these perceptions to teaching methods, student achievement and digitalisation of teaching processes. In addition, the relationship between teachers' digital competences and their perceptions of digital teaching is also analysed. Since science courses require the concretisation of scientific concepts, the use of digital technologies has a great potential in this field. Research shows that teachers' perceptions of digital teaching affect their level of integrating digital tools into in- and out-of-class activities and that digital competences need to be increased.

As a result, digital teaching has a priority place in teachers' professional skills as a necessity of contemporary teaching processes. In this context, improving science teachers' perceptions of digital teaching is critical in terms of providing students with the skills required by the digital age. This article aims to provide a direction for future research on this subject and to contribute to a broader perspective of digital teaching perception in the context of science education.

Keywords: Science, Digital teaching, Digital transformation, Educational technologies

INTRODUCTION

Today, the rapid increase in technological developments has made the need to be aware of these innovations and to follow developments one of the main interests of human beings. It is of great importance that technology, which

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develops depending on the needs of the society, is understood and adopted by the individuals of this society (Baldemir, İç, & Tutak, 2022). Science has become an indispensable part of human life by progressing rapidly today. Technology, which emerged as a result of science, has transformed human life by offering conveniences in almost every aspect of life. Technological innovations are generally shaped by the needs of society or changes in the development of existing technologies. Technology can be defined as a rational discipline designed by human beings in an effort to dominate nature by using science. Paul Saetller, an important name in the history of instructional technology, defines technology as follows: 'Technology (derived from the Latin verb 'texere'; meaning to weave, to build) is not limited to the use of machinery, but rather refers to the process of creating and structuring' (İç & Tutak, 2018). This definition emphasises that technology is not only about tools and machines, but also about the creative application of scientific knowledge.

James Finn, an important name in the field of educational technology, defines technology as follows: 'Technology is a perspective that goes beyond the use of machinery to include systems, processes, management and control mechanisms. It refers to the endeavour to produce solutions to both human-induced and objective problems in accordance with the degree of difficulty, technical solution possibilities and economic values of these problems.' Albert Einstein, on the other hand, defines science as an endeavour to achieve harmony between irregular sense data and logically organised thinking. Science is a process that questions and analyses the natural world with various methods and techniques and presents the findings obtained with clear, valid and reliable generalisations. When these data presented by science are transformed into a product with the help of tools, equipment or instruments, this process is called technology (Erbek, Asiltürk, & Kahyaoğlu, 2023). In this context, this complementary relationship between science and technology constitutes a fundamental basis for solving problems and developing innovations in the modern world.

With the rapid development of information and technology, especially with the internet becoming an indispensable part of life, the digital world has gained an important place in the lives of individuals. Such rapid advancement of technology has led to the emergence of significant differences between generations (Önal Karakoyun & Asiltürk, 2022). While one generation made an effort to learn technology, another generation had the opportunity to grow up in an environment directly intertwined with technology. Today's primary school students, defined as Generation Z, who find it difficult to imagine a world without technology and digital tools, grow up in a digital environment and participate in educational processes (Bağır, Önal Karakoyun, & Asiltürk,

2022). This situation allows students to participate in learning activities without any time and space limitations. New generation students prefer to learn from virtual experiences instead of real experiences, turn to digital resources instead of printed materials, and prefer to take photos of presentations instead of listening to what the teacher tells during the lesson (Önal Karakoyun & Asiltürk, 2021). In addition, they exhibit digital habits such as texting, surfing the internet and playing games during the lesson. Due to their limited attention span, they want to access information quickly, prefer learning by discovery instead of traditional learning methods, and tend to perform multiple tasks at the same time. This changing student profile inevitably affects the roles of teachers, who are the biggest guides of students in the learning process, and the expectations from students (Tutak et al., 2009). In this context, the development of teaching methods and approaches appropriate to the needs of students in the digitalised world is critical in increasing the effectiveness of the educational process.

In order to create an effective learning process, teachers need to analyse the characteristics of the new generation called digital natives, develop teaching methods appropriate to these characteristics and shape their learning processes accordingly (Alcourt & Yılmaz, 2021). In this context, a teacher profile emerges that can use instructional technologies effectively, guide in-class and out-of-class learning processes, and integrate digital tools such as mobile phones, internet and social networks into teaching activities without time and place limitations. This new teacher profile consists of individuals who use technological applications in in-class activities, carry out design-based teaching activities, evaluate the internet as a learning environment and adopt game-based learning methods in teaching-learning processes. Teachers with these characteristics are defined as ‘digital teachers’ in today’s education world (Dias Trindade, Moreira, & Ferreira, 2020).

Today, most of the students receiving teacher education in Faculties of Education consist of the generation born between 1980 and 2000 and called Generation Y. This generation, which is compatible with the digital environment, needs to graduate with digital teacher qualifications that can meet the requirements of the digital age, especially to meet the needs of today’s primary school students.

When the existing literature is examined, it is observed that the digital age is progressing rapidly and education is directly affected by these digital developments. This study focuses on how pre-service and in-service science teachers actively use technology in their professional and pre-professional lives and how they can transfer this use to education. Determining pre-service science teachers‘ and teachers’ perceptions of digital teaching is important in terms of

ensuring the integration of technology into education and training processes and eliminating the deficiencies in these processes. The aim of the study is to contribute to the adoption of the concept of digital teaching by pre-service science teachers and teachers, to eliminate their deficiencies in this field and to create the necessary infrastructure for them to raise individuals in accordance with the requirements of the digital age.

Research Questions

Within the scope of this research, answers to the following questions were sought:

1. Which research methods, sample selection criteria and data collection tools are used to determine science teachers‘ and pre-service teachers’ perceptions of digital teaching?

2. How do the studies reveal science teachers‘ and pre-service science teachers’ perceptions of digital teaching and in which dimensions are these perceptions evaluated?

3. What are the suggested research topics to be addressed in the future to determine science teachers‘ and pre-service teachers’ perceptions of digital teaching?

Material and Method

This study aims to reveal the types of studies conducted to determine science teachers‘ and pre-service teachers’ perceptions of digital teaching and the connections between them, and to guide future research in this way. In this direction, document analysis method was used (Minner et al., 2010; Baran & Bilici, 2015). Document analysis is a systematic method that covers the processes of scanning, finding, examining and evaluating existing sources within the framework of a specific purpose (Karasar, 2005). This method was carried out in four basic stages: source screening, determination of selection criteria, screening process and data analysis (Karaçam, 2013; Baran & Bilici, 2015). These stages of document analysis are discussed in detail below.

Screening Method and Determination of Selection Criteria

In this study, document analysis method was used. In the first stage of the study, certain criteria and keywords were defined to examine the perceptions of science teachers and pre-service teachers about digital teaching. Articles published in refereed journals or open to international access between 2010 and 2023 were included in the scope of the study. These studies have been carried out since the early 2000s in order to examine the effects of mobile learning applications on educational processes.

Screening Process

In this study, keywords suitable for the research topic were determined in order to reach the articles on science teachers‘ and pre-service teachers' perceptions of digital teaching. A comprehensive search was carried out in ISI Web of Science, EBSCOHost, Science Direct, ERIC databases and Google Scholar search engines through the determined keywords. The studies obtained as a result of the search were examined in detail in terms of title and content, and those that were not directly related to the research topic were excluded from the scope of the research. At the end of this process, a total of 4 articles were selected to be included in the research. The bibliographies of the included articles were also examined to identify articles that may have been overlooked during the search. However, no additional study was found with this method.

Analysis Process

In this study, during the content analysis process of the articles, categories such as research topic, method used, study group, data collection tools, data analysis techniques, findings and main conclusions were taken into consideration. With this approach, it was aimed to evaluate the studies within the scope of the research in a systematic way.

CONCLUSION AND DISCUSSION

In this study, the articles selected as a result of the search conducted in accordance with the criteria detailed in the methodology section were analysed in terms of research topic, method used, study group, data collection tools, data analysis techniques, findings and main conclusions.

Avidov-Ungar and Tsybulsky (2021) aimed to examine the effect of teachers enrolled in a master's programme in teacher education on their perceptions of the teaching role in the digital age through participation in an online course using a project-based learning (PBL) approach. The main topic of the study is to understand how learning experiences in an online PBL environment shape teachers' perceptions of learning in personal, pedagogical and social aspects and their reflections on their teaching roles in the digital age. Data were collected between 2014 and 2016. The study group consisted of 55 participants whose personal and demographic information was collected through a questionnaire and 105 participants who provided reflective reports on their course experiences. Questionnaires and reflective reports were used as data collection tools. The collected data were analysed using content analysis method. The analysis revealed that the participants considered their learning experiences from personal, pedagogical and social perspectives and that these experiences shaped their perceptions of their teaching roles in the digital age. Moreover, it was determined that exposure to PBL approach in online environment directly influenced the participants' perceptions of the learning process and their

teaching roles. The research findings emphasise the importance of providing teachers with access to a learning experience that combines online learning with hands-on teaching practices in order for them to better understand and embrace their roles in the digital age. Such an experience supports teachers to undergo a socialisation process in accordance with the requirements of the digital age. The practical implications of the study provide recommendations that can guide the design of training programmes for teachers' professional development processes in the digital age.

In their research, Garzón-Artacho et al. (2021) aimed to analyse the digital competence levels of teachers based on the increasing impact of Information and Communication Technologies (ICT) in the field of education and the need to integrate teachers' digital skills into their professional practices. The main topic of the research is to examine the digital competence levels of teachers working in the continuous learning phase in the Autonomous Region of Andalusia (Spain) and how these skills are associated with variables such as age, teacher education and school type. The study was based on a cross-sectional methodological design and was carried out with a quantitative approach. An ad hoc questionnaire based on the European framework programmes on teacher digital competences was used as a data collection tool. The study group consisted of 140 teachers working in the continuing education phase in the Andalusia region. The data were analysed using statistical analysis methods, with a particular focus on the different dimensions that make up teachers' digital competences. The findings of the study showed that teachers' overall digital competence levels were low. In particular, deficiencies were observed in skills such as digital content creation, information literacy and problem solving. However, teachers were found to have a higher skill level in digital content communication and collaboration. Factors such as age, level of professional education and type of school were found to be effective on the development of digital competences. In conclusion, this study highlights that teachers' digital skills need to be developed and more effective training programmes are needed for the integration of these skills into professional practices. Furthermore, the findings reveal the importance of considering personal and organisational factors in the development of digital competences and provide guidance for the development of educational policies in this field.

Aksakal ve ark. (2021) araştırmalarında fen bilgisi öğretmenleri ve öğretmen adaylarının dijital öğretmenlik algılarını belirlemeyi amaçlamaktadır. Araştırma, hem nicel hem de nitel yöntemlerin bir arada kullanıldığı karma yöntem araştırmalarından açıklayıcı desen kullanılarak gerçekleştirilmiştir. Çalışma grubunu, 2017-2018 eğitim-öğretim yılında Doğu Anadolu Bölgesi'ndeki iki farklı üniversitede Fen Bilgisi Öğretmenliği Anabilim Dalı'nda son sınıfta öğrenim gören öğretmen adayları ve bu illerde görev

yapan fen bilgisi öğretmenleri oluşturmuştur. Katılımcılar, amaçlı örnekleme yöntemlerinden ölçüt ve maksimum çeşitlilik örneklemesi dikkate alınarak seçilmiştir. Veri toplama araçları olarak, araştırmacılar tarafından geliştirilen Dijital Öğretmenlik Algısı Ölçeği ve açık uçlu soru formu kullanılmıştır. Nicel verilerin analizi için SPSS 15 paket programı, nitel verilerin analizi için ise betimsel analiz tekniği uygulanmıştır. Analiz sonuçları, dijital öğretmenlik algı düzeylerinin cinsiyet, hizmet süresi ve kodlama-tasarım gibi dersleri alma durumları bakımından anlamlı bir fark göstermediğini ortaya koymuştur. Ancak, katılımcıların sosyal ağ kullanımı (kendi sosyal ağlarının bulunma durumu, sosyal ağlarda arkadaşlık ilişkileri ve bir WhatsApp grubuna üyelik durumu) ile dijital öğretmenlik algıları arasında pozitif yönde anlamlı bir ilişki bulunmuştur. Araştırma bulguları, öğretmenlerin öğrencileriyle kurdukları WhatsApp gruplarını, öğrencilerin sorularını yanıtlamak, duyurular yapmak ve sorunlarını dinlemek gibi amaçlarla kullandıklarını göstermektedir. Bununla birlikte, bu tür sanal etkileşimlerde öğretmenlerin seviyeyi koruma ve yalnızca dersle ilgili paylaşımlar yapma gerekliliğine vurgu yaptıkları belirlenmiştir. Katılımcılar, eğitimde dijitalleşme ile öğretmenlerin kendilerini sürekli güncellemelerinin gerekliliğini vurgulamış, dijital araçların öğretmenin iş yükünü hafiflettiği ve rehberlik pozisyonunu güçlendirdiği görüşünü paylaşmışlardır. Bununla birlikte, dijital ortamda rehberlik yapılabileceği fikri yaygın olmakla birlikte, yüz yüze rehberliğin daha etkili olacağı yönünde görüşler de ifade edilmiştir. Sonuç olarak, bu çalışma, fen bilgisi öğretmenlerinin ve adaylarının dijital öğretmenlik algılarını belirleyerek, dijitalleşmenin öğretmenlik mesleğine etkilerine dair önemli bulgular sunmaktadır. Bu bağlamda, öğretmenlerin dijital araçları etkili kullanmalarını destekleyecek eğitim programlarının geliştirilmesi ve dijitalleşme süreçlerinde öğretmenlerin rehberlik rollerini güçlendirecek stratejilerin benimsenmesi önerilmektedir.

Walan (2020) araştırmasında öğretimin neredeyse tamamen dijital teknolojiye dayandığı fen bilgisi sınıflarında neler yaşandığını incelemeyi amaçlamıştır. Araştırmanın temel konusu, dijital teknolojinin fen bilgisi öğretimine nasıl entegre edildiğini ve bunun pedagojik süreçler ile öğrenci deneyimlerine etkilerini belirlemektir. Çalışmaya iki ortaokul fen bilgisi öğretmeni ve onların yedinci sınıf öğrencileri katılmıştır. Veri toplama sürecinde sekiz ders gözlemi (toplamda yaklaşık 9,5 saat) ve öğretmenlerle yapılan 9 saatlik görüşmelerden yararlanılmıştır. Verilerin analizi, Teknolojik Pedagojik İçerik Bilgisi (TPACK) çerçevesinin bir modifiye edilmiş versiyonuna dayanılarak gerçekleştirilmiştir. Bulgular, öğretmenlerin dijital teknoloji kullanımı konusunda özgüvenli olduklarını, önceden belirlenmiş dijital çalışma materyallerini kullandıklarını ve gerektiğinde ek materyallerle desteklediklerini ortaya koymuştur. Öğretmenler, dijital teknolojinin öğrenci motivasyonunu artırdığı ve

değerlendirme süreçlerini kolaylaştırdığı için öğretim süreçlerini olumlu yönde etkilediğini ifade etmişlerdir. Ayrıca, dijital araçlara erişimin öğretime çeşitlilik kazandırdığını ve bireyselleştirilmiş öğrenme süreçlerini desteklediğini belirtmişlerdir. Bununla birlikte, fizik, kimya ve biyoloji gibi farklı derslerde dijital teknoloji kullanımında önemli bir farklılık tespit edilmemiştir. Ancak, dijital teknolojinin içerik bilgisiyle ilişkisi sınırlı kalmıştır. Öğretmenler, düşük başarı düzeyindeki öğrencileri destekleme ve dijital teknolojiyle sorgulamaya dayalı öğretimi etkili bir şekilde gerçekleştirme konusunda zorluklar yaşadıklarını belirtmişlerdir. Araştırmanın sonuçları, TPACK çerçevesinin dijital teknolojiyi yoğun olarak kullanan öğretim bağlamlarını analiz etmek için etkili bir araç olduğunu göstermektedir. Ancak, dijital teknolojinin yalnızca araçsal bir entegrasyon yerine öğretimin her yönüne nüfuz ettiği durumlarda daha geniş pedagojik yaklaşımlar geliştirilmesi gerektiği de vurgulanmıştır. Bu çalışma, dijital teknolojilerin fen bilgisi öğretiminde kullanımına yönelik anlayışımızı derinleştirmekte ve daha etkili dijital entegrasyon stratejilerinin gerekliliğini ortaya koymaktadır.

COMMENTS AND SUGGESTIONS

Digitalisation is reshaping the professional roles of teachers by transforming educational processes. Understanding science teachers‘ and pre-service teachers’ perceptions of digital teaching is critical for making technology integration in education more effective. Research in the literature reveals that digital teaching perceptions have a decisive impact on teachers’ professional skills and teaching methods.

Research shows that digital tools provide benefits such as easing teachers’ workload, supporting individualised learning processes and increasing student motivation. However, in order for teachers to use these tools effectively, they need to increase their technological competences and be guided in the integration of these tools into teaching processes. In particular, frameworks such as project-based learning (PBL) and Technological Pedagogical Content Knowledge (TPACK) play an important role in developing teachers’ digital skills.

However, research emphasises that teachers’ perceptions of digital teaching are limited in areas such as social networking, digital content creation and problem solving, so a more comprehensive training approach is needed. Strategies should be developed to enable teachers to use digital tools not only as a communication tool but also as a part of pedagogical processes.

Science teachers experience difficulties in implementing inquiry-based teaching methods with digital technologies and need additional help in supporting low achieving students. This situation reveals that teachers should be supported more in order to adapt to the requirements of the digital age.

Recommendations

1. Digital Training Programmes: In order to develop science teachers' digital skills, training programmes should be designed that specifically support digital content creation, problem solving and inquiry-based teaching methods.

2. Practical Applications and Guidance: Practical trainings should be organised to provide guidance to teachers on the effective use of digital tools and these trainings should be integrated into teachers' in-class and out-of-class teaching processes.

3. Use of Digital Social Networks: Teachers should be encouraged to use social networks to interact with their students and guidance should be provided to increase the pedagogical effectiveness of these platforms.

4. Strategies for Low Achieving Students: Specific strategies should be developed on how digital technologies can be used more effectively for low-achieving students.

5. Literature Based Guidance: Literature-based course contents and applied projects should be offered in faculties of education to improve pre-service science teachers' perceptions of digital teaching.

In conclusion, adapting to the teaching requirements of the digital age will increase the success of both teachers and students in educational processes. Providing continuous support and guidance to enable science teachers to use digital tools effectively for pedagogical purposes will be an important step to increase the efficiency of digitalisation in education.

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LABORATORY ANXIETY AND SCIENCE LABORATORY ANXIETY OF SCIENCE TEACHERS

Gülen Önal Karakoyun[1]

SUMMARY

This review study aims to address the causes, effects and solutions of laboratory anxiety observed in teachers and pre-service teachers despite the critical role of science laboratories in teaching processes. Laboratory studies are an indispensable part of science education in terms of developing students' science process skills and supporting their theoretical knowledge with practical experiences. However, teachers' anxieties about laboratory practices may prevent these processes from being carried out effectively. This situation may negatively affect both science teachers' teaching competences and students' learning gains from laboratory experiences.

The research discusses the sources of laboratory anxiety in the literature through factors such as inadequate laboratory equipment, time management problems, safety concerns, anxiety about correct application of experimental procedures and lack of technical knowledge. Strategies to reduce these concerns of science teachers are associated with professional development programmes, hands-on laboratory trainings, awareness-raising studies on safety procedures and collaborative teaching models.

This study aims to better understand the laboratory anxiety of science teachers and to provide suggestions to reduce the effects of this anxiety in teaching processes. In order to increase the effective use of science laboratories, it is suggested to develop structured training programmes to support teachers' professional competencies and innovative approaches to classroom practices. The study emphasises that managing and reducing laboratory anxiety will directly contribute to the quality of science education.

Keywords: Science, Science Laboratory, Laboratory Anxiety, Professional skills

INTRODUCTION

Rapid advances in science and technology have directly affected daily life, making science education an indispensable requirement for understanding and guiding the modern world. Science offers an interdisciplinary structure that enables individuals to understand technology, use scientific concepts

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in their daily lives, and systematically comprehend the planet we live on (Aydoğdu, 2017). Rapid developments in fields such as artificial intelligence, biotechnology and environmental sciences allow individuals with science education to better understand the potential of these technologies and integrate these innovations into their lives. This situation provides important social and economic contributions. Science education supports the development of skills such as productivity, investigative thinking, decision making, problem solving and analytical thinking in individuals. Science also forms the basis of skills such as systematic thinking, analysing and understanding scientific processes (Haşiloğlu & Göğebakan, 2021). In this context, science education not only directs individuals to academic success, but also makes them well-equipped individuals who can solve the problems encountered in the modern world. It is clear that science education plays a critical role in creating an environment in which individuals can contribute effectively at both personal and societal levels.

Science education aims to enable individuals to have a mindset that can relate to life, analyse the results obtained through observation and research, and transfer this knowledge to different environments and settings (Albion et al., 2016). In cases where science education is not given the necessary importance, it will not be possible for individuals to develop problem-solving skills, and their ability to make sense of natural phenomena and conduct research will not develop sufficiently. For this reason, teachers have important responsibilities for raising future individuals as qualified, adaptable to developing technologies and science literate. Science teachers not only assume the role of transferring knowledge, but also teach students how to use knowledge effectively and motivate them to continuously learn, discover and innovate. In this process, teachers enrich students' learning experiences by using various methods (Baysen & Baysen, 2022). One of these methods is laboratory practices, which is an integral part of science education. Laboratory methods offer students the opportunity to experience scientific process skills, transform theoretical knowledge into practice, and learn through research. In this context, the effective use of laboratory methods plays a key role in achieving the goals of science education.

Research on the importance of laboratories in science education reveals that these environments enable students to learn science subjects more effectively and meaningfully. Laboratories are interactive learning environments where students can learn scientific concepts and phenomena through direct experience or observation, construct scientific knowledge and develop basic scientific thinking skills. In addition, these environments provide a platform where students interact with each other and actively participate in the learning process (Watters & Gins, 1994).

The contributions of laboratory studies on science education are diverse:

- Self-confidence and Curiosity: Laboratory studies increase students' self-confidence and satisfy their curiosity about science subjects.
- Skill Development: Students' experiences in different environments contribute to the development of their skills.
- Learning Motivation: These activities increase students' motivation for learning.
- Mental and Physical Harmony: It supports mental processes and physical skills to work in harmony.
- Problem Solving: It develops problem solving skills and strengthens analytical thinking skills.
- Experimental Interpretation: Encourages critical thinking by enabling the interpretation of data obtained through experimentation.
- Relationship between Science and Daily Life: It facilitates the ability to associate science with daily life (Kurbanoğlu, 2014).

In conclusion, laboratory practices are a fundamental component that makes science education more effective and meaningful by enabling students to actively participate in scientific knowledge. It is clear that these environments play an important role in developing both students' scientific process skills and their capacity to apply science knowledge in daily life.

Science laboratories have an important role in the teaching of science. The use of laboratories in science lessons provides an effective method for students to develop experimental skills by enabling them to hypothesise, identify variables and gain scientific process skills. Science teachers play a key role in achieving the goals of laboratories by guiding students to learn by doing and experiencing. In this process, teachers perform experimental demonstrations and applications in order to deepen students' understanding and learning of science subjects (Bilen, 2023).

Research shows that science teachers' knowledge, skills, and attitudes in laboratory use directly affect students' gains from laboratory experiences. Teachers' effective planning and management of laboratory studies increases students' interest in science and helps them develop scientific thinking skills. Therefore, it is of great importance to develop pre-service teachers' laboratory skills and attitudes towards laboratories in a positive way. Determining pre-service teachers' attitudes towards laboratories before graduation and supporting these attitudes positively is an important step that will reflect positively on future teaching processes (Hamza, 2013).

The concept of attitude refers to the cognitive, affective and behavioural tendencies of individuals towards objects, events or subjects and is therefore

an important factor in learning and teaching processes. Tavşancıl (2019) states that attitude is not directly innate, it is learned through an individual's life experiences and shapes positive or negative behaviours. Factors that shape students' attitudes towards science courses include age, home environment, teaching methods, family attitudes and past experiences. Osborne (2003) states that laboratory practices can positively or negatively affect students' attitudes towards science courses (Espinosa Tameta & Castillo, 2015). However, for some students, laboratory environments can be challenging and this can lead to negative attitudes.

Anxiety appears as an affective obstacle in learning processes. Freud (1969) defines anxiety as 'an unpleasant emotional state', while science anxiety is defined as students' feeling of stress and tension towards science concepts, teachers and activities. This situation can manifest itself physically with symptoms such as sweaty palms, stomach ache, headache and psychologically with reactions such as tension, nervousness and restlessness. It is stated that past negative science classroom experiences, gender and stereotyped social stereotypes are effective in the formation of science anxiety (Ural, 2016).

In this context, this study examines the laboratory anxiety levels of pre-service science teachers and the effects of this anxiety on their teaching processes. Reducing science laboratory anxiety and developing positive attitudes of pre-service science teachers will contribute to their perception of science laboratories as an effective learning environment and increase their ability to manage these environments.

Research Questions

Within the scope of this research, answers to the following questions were sought:

1. Which research methods, sample selection criteria and data collection tools are used to determine science teachers' science laboratory anxiety?

2. How do the studies reveal science teachers' science laboratory anxiety and in which dimensions are these perception levels evaluated?

3. What are the suggested future research topics for determining science teachers' science laboratory anxiety?

Material and Method

This study aims to reveal the types of studies conducted to determine science teachers' science laboratory anxiety and the connections between them, and to guide future research in this way. In this direction, document analysis method was used (Minner et al., 2010; Baran & Bilici, 2015). Document analysis is a systematic method that covers the processes of scanning, finding, examining and evaluating existing sources within the framework of a specific purpose

(Karasar, 2005). This method was carried out in four basic stages: source screening, determination of selection criteria, screening process and data analysis (Karaçam, 2013; Baran & Bilici, 2015). These stages of document analysis are discussed in detail below.

Screening Method and Determination of Selection Criteria

In this study, document analysis method was used. In the first stage of the study, certain criteria and keywords were defined to examine science teachers' science laboratory anxiety. Articles published in refereed journals or open to international access between 2010 and 2023 were included in the scope of the study. These studies have been carried out since the early 2000s in order to examine the effects of mobile learning applications on educational processes.

Screening Process

In this study, keywords suitable for the research topic were determined in order to reach the articles on science teachers' science laboratory anxiety. A comprehensive search was carried out in ISI Web of Science, EBSCOHost, Science Direct, Science Direct, ERIC databases and Google Scholar search engines. The studies obtained as a result of the search were examined in detail in terms of title and content, and those that were not directly related to the research topic were excluded from the scope of the research. At the end of this process, a total of 4 articles were selected to be included in the research. The bibliographies of the included articles were also examined to identify articles that may have been overlooked during the search. However, no additional study was found by this method.

Analysis Process

In this study, during the content analysis process of the articles, categories such as research topic, method used, study group, data collection tools, data analysis techniques, findings and main conclusions were taken into consideration. With this approach, it was aimed to evaluate the studies within the scope of the research in a systematic way.

CONCLUSION AND DISCUSSION

In this study, the articles selected as a result of the search in accordance with the criteria detailed in the method section were analysed in terms of research topic, method used, study group, data collection tools, data analysis techniques, findings and main results.

Güven et al. (2015) aimed to examine the effects of case-based laboratory activities applied in chemistry laboratory courses on the laboratory anxiety levels of pre-service science teachers. The main subject of the study was to determine the effect of case-based activities on reducing laboratory anxiety and how this approach shaped pre-service science teachers' perceptions of

laboratory processes. The participants of the study consisted of 63 pre-service science teachers studying in the first year at Muğla Sıtkı Koçman University. Participants were randomly assigned to experimental and control groups. In the experimental group, laboratory lessons were conducted with case-based activities for six weeks, while in the control group, traditional methods were applied during the same period. In the data collection process, Chemistry Laboratory Anxiety Scale was administered to both groups as pre and post-test. In addition, open-ended questions were applied only to the experimental group. The sub-dimensions of the scale such as 'using tools and chemicals', 'working with other students', 'collecting data' and 'allocating enough time' were observed. Quantitative and qualitative methods were used together for data analysis; the scale results were evaluated by statistical analysis, while the data obtained from open-ended questions were analysed by descriptive analysis method. The findings of the study revealed that case-based activities significantly reduced pre-service teachers' laboratory anxiety and that the participants working with this method developed a more positive perspective on laboratory practices. The pre-service teachers in the experimental group stated that case-based activities provided more meaningful and practical learning in their teaching processes. On the other hand, traditional methods in the control group did not produce such positive effects. As a result, case-based laboratory activities were found to be effective in reducing pre-service teachers' anxiety about laboratory processes and increasing their willingness to use these methods in teaching practices. The study offers suggestions for the dissemination of case-based activities in laboratory courses and the integration of this method into teacher education. It is emphasised that this approach is an important tool for both increasing the efficiency of laboratory courses and contributing to the professional development of pre-service science teachers.

Berber (2013) aimed to determine pre-service physics teachers' concerns about physics laboratory, the difficulties they experience in the laboratory environment, their expectations from this environment, their preferences and opinions. In the study in which mixed method approach was adopted, quantitative and qualitative methods were used together. In the collection of quantitative data, the 'Physics Laboratory Anxiety Scale' developed by the researchers was applied to 245 pre-service teachers. In addition, in-depth interviews were conducted with 20 pre-service teachers selected based on the survey model. As a result of the analysis of the data, it was determined that pre-service teachers had difficulties in drawing graphics, using materials, understanding the purpose of experiments and unit conversion in physics laboratory applications. It was determined that the participants preferred group work because they did not feel confident enough in individual work and preferred theoretical physics courses to physics laboratory applications. In addition, it was observed that there was a

constant anxiety towards laboratory applications and the anxiety levels of male pre-service teachers were higher than those of female pre-service teachers. These findings provide important clues for the development of teaching methods and supportive arrangements in physics laboratory.

Kırbaşlar, Veysioğlu, and Özsoy-Güneş (2015) aimed to examine the relationship between pre-service teachers' self-efficacy in the laboratory and their anxiety towards chemistry laboratory. In the study in which relational survey model was used, 'Laboratory Self-Efficacy Scale (LSES)' developed by Ekici (2009) and adapted to pre-service science teachers and 'Chemistry Laboratory Anxiety Scale (CLAS)' developed by Bowen (1999) and adapted to Turkish by Azizoğlu & Uzuntiryaki (2006) were used as data collection tools. The study group of the research consisted of 363 pre-service science teachers. As a result of the analysis of the data, it was determined that there were significant and negative relationships between LSES and CLAS scores. While a significant relationship was found between gender and type of secondary education in terms of LSES scores, no significant relationship was found with the frequency of laboratory use during secondary and university education. In terms of CLAS scores, there was no significant difference in gender, grade level, type of secondary education and frequency of laboratory use in secondary education, while frequency of laboratory use during university education made a significant difference. These results show that pre-service teachers' laboratory experiences have an effect on anxiety and self-efficacy and provide important data for regulations for laboratory education.

Ghimire (2023) aimed to investigate the causes of undergraduate chemistry students' anxiety. In the study, in which phenomenological research approach was adopted, in-depth answers were tried to be obtained about the lived experiences and perceptions of students and teachers about the anxieties created by the chemicals used in chemistry laboratories. Data were collected through in-depth interviews with students who experienced anxiety in chemistry lessons. As a result of the analyses, it was determined that language problems, teaching methods and factors related to the perception of chemistry were at the root of the students' anxiety. It was determined that the most important source of anxiety of the students was language problems. The study shows that understanding the causes of science anxiety can help instructors design more effective lessons. It was emphasised that if teachers recognise the causes of students' chemistry anxiety, they can support them to reduce these anxieties and enable students to focus more on course activities. It was stated that strategies such as using visual materials, applying the question-answer method and creating activities that require active participation of students can contribute to overcoming students' passive attitudes in the lessons. These results provide valuable information for the restructuring of teaching approaches in chemistry education.

COMMENTS AND SUGGESTIONS

Within the scope of this study, methods for understanding science teachers' anxieties towards science laboratories, evaluation of the perception levels of these anxieties, and evaluations on the issues that can be addressed in this field in the future are presented. The study aims to identify the main trends and gaps in the literature on teachers' laboratory anxiety.

Studies on determining science teachers' laboratory anxiety generally adopt a mixed method approach and evaluate quantitative and qualitative data together. In sample selection, pre-service teachers or actively working science teachers are generally preferred. Sample groups are generally determined by random or purposive sampling methods. While standardised scales such as the 'Chemistry/Physics Laboratory Anxiety Scale' are frequently used as data collection tools, qualitative methods supported by in-depth interviews and open-ended questions provide more detailed insights into teachers' anxiety. These methods provide a suitable basis for understanding the main sources of laboratory anxiety, the intensity of anxiety, and the areas affected by anxiety.

Research evaluates science teachers' laboratory anxiety in certain dimensions. These dimensions include the use of tools and equipment in the laboratory environment, correct application of experimental procedures, time management, safety concerns, and lack of technical knowledge. Anxiety is closely related to teachers' perceptions of individual efficacy, their need for group work and their self-efficacy towards laboratory practices. In particular, innovative approaches such as case-based learning were found to be effective in reducing anxiety and teachers developed a more positive perspective towards laboratory processes. These findings provide important clues for structuring education to improve teachers' perceptions of laboratory practices.

The following topics are suggested for future research on science teachers' laboratory anxiety:

- The effect of demographic factors such as gender, experience and education level on anxiety: Especially comparing the anxiety levels of pre-service and senior teachers can provide important data in this area.
- The effect of different teaching approaches: It is suggested to examine the effect of case-based learning, problem-based learning and simulation-based laboratory activities on laboratory anxiety.
- The role of teacher education programmes: The effect of programmes that prepare science teachers for laboratory processes on reducing anxiety can be addressed more comprehensively.
- The effect of laboratory infrastructure and equipment deficiencies: It can be emphasised how the lack of laboratory equipment, especially in

schools in underdeveloped regions, reflects on teacher anxiety and the development of suggestions for the solution of this situation.

- Digital and remote laboratory applications: How virtual laboratory experiences can play a role in reducing anxiety can be investigated.

Effective use of science laboratories is closely related to understanding and managing science teachers' laboratory anxieties. Effective evaluation of the methods for identifying these anxieties and the findings obtained is critical both to support teachers' professional development and to increase students' science process skills. Future studies may provide a deeper understanding of laboratory anxiety and contribute to the development of more innovative and effective strategies to reduce this anxiety.

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MATHEMATICS AND INTERDISCIPLINARY RELATIONS FROM AN ACADEMIC PERSPECTIVE

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Abstract

The relationships between mathematics and other disciplines are recognized as fundamental factors that enrich and deepen the learning and understanding processes. This study aims to evaluate the contribution of the relationships between mathematics and various disciplines to mathematics education and their impact on teaching methods. The research comprehensively analyzes the integration of mathematics with various fields, from physics to art, engineering to music, economics to medicine, and how this integration can be incorporated into educational processes. As a research method, a systematic review of relevant publications was selected, and the information obtained from this review focused on the advantages of interdisciplinary approaches in mathematics education. The study provides a theoretical framework and recommendations on how interdisciplinary relationships can be established in mathematics education and how these relationships can positively contribute to student learning. The findings offer important insights into how mathematics instruction can be improved and educational processes enhanced, guiding teachers. Additionally, the research discusses the challenges encountered in implementing interdisciplinary approaches and suggests methods to overcome these challenges. In conclusion, the study emphasizes the importance of accepting interdisciplinary relationships in mathematics education and provides recommendations on how these relationships can positively impact students' academic achievements and individual development. This work aims to promote innovative approaches in mathematics education and foster wider acceptance of interdisciplinary education in the field.

Keywords: Mathematical Integration, Interdisciplinary Approach, Integration in Education.

Introduction

When we look at history, we see that the roots of different interdisciplinary studies go very deep. For example, while a physicist, mathematician, astronomer, philosopher and theologian like Isaac Newton laid the foundations of higher mathematics; Theoretical physicist Albert Einstein carried out studies

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that made significant contributions to chemistry and mathematics. Likewise, Galileo Galilei, a physicist, mathematician, astronomer and engineer, laid the foundations of modern science and is an important example of interdisciplinary studies. In educational programs, associating a course with different courses is called interdisciplinary teaching or approach. While Jacobs (1989) defines interdisciplinary approach as the processing of methodological knowledge of different disciplines on a concept, subject or experience; Yalçın (2013) explains this approach as combining or covering two or more disciplines. The basis of the interdisciplinary approach lies in a conscious integration and association process by the teacher. In this process, interdisciplinary studies involving many branches of science such as mathematics have an important place, because mathematics is a science that inherently deals with relationships and is used by many branches of science (Bolat, Turna, & Keskin, 2012).

Mathematics is a branch of science that develops both within itself and by making connections with other disciplines. Bingölbali and Coşkun (2016) stated that concepts in mathematics are related to each other and develop based on previous knowledge. This association enables mathematics to be applied in a wide range of areas, from science to art. The National Council of Teachers of Mathematics (NCTM) defined content and process standards in mathematics education with the Principles and Standards of School Mathematics document published in 2000. This document emphasizes interdisciplinary understanding by aiming to provide students with mathematical association skills. The mathematics programs of the Ministry of National Education in 2005 and 2013 also emphasize the importance of imparting mathematical thinking and interdisciplinary connections to students (MEB, 2009, 2013).

The intertwining between mathematics and other disciplines offers students the opportunity to learn subjects in a more meaningful and easier way, increases the permanence of their knowledge and skills, and contributes to the development of positive attitudes towards mathematics (MEB, 2013). One of the main goals of mathematics education programs is to enable students to solve the problems they encounter by associating them with mathematical concepts; This goal is consistent with the process standards established by NCTM. In the definition made by Bingölbali and Coşkun (2016), mathematical connectivity; It consists of four main components: connection between concepts, relationship between different representations of concepts, and association with real life and various disciplines. This skill helps students develop their high-level thinking abilities and increase their motivation to learn, thanks to the connections established between courses. Michelsen (2005) and Turna and Bolat (2015) emphasized the importance of this approach in education, but stated that interdisciplinary studies in Turkey are not given enough importance. Although teachers view

this approach positively (Karakuş & Aslan, 2016; Aladağ & Şahinkaya, 2013; Coşkun, 2013), there are difficulties encountered in effectively integrating interdisciplinary teaching.

Aim

The main purpose of this study is to examine in depth the interactions between mathematics and other disciplines, to investigate how these interactions can be integrated into mathematics education, and to evaluate the effects of interdisciplinary approaches on mathematics learning.

Method

This study was designed to understand the interactions between mathematics and other disciplines and the integration of these interactions into mathematics education. An extensive literature review was conducted to analyze the effects of interdisciplinary approaches on mathematics teaching. The research aims to comprehensively describe and evaluate the studies in the relevant literature. In this process, the relationships between mathematics education and various disciplines such as physics, engineering, computer science, economics, biology, philosophy, medicine, astronomy, geography, business, music and art were taken into account. The findings were analyzed to reveal the contributions and potential challenges of interdisciplinary interactions to mathematics learning.

Theoretical Framework

Mathematics has a deep and complex relationship with other sciences and disciplines. Mathematics is a fundamental science and provides a strong foundation for other scientific fields and has a tight integration with these disciplines. Here are some main points about the relationship of mathematics to other disciplines:

Physical

In the field of physics, mathematical modeling has a central role in understanding and predicting natural phenomena and events. In this process, mathematical equations, such as Isaac Newton's laws of motion, are used to represent physical realities. Mathematical physics is a branch of science that explores the deep connection between the disciplines of physics and mathematics. In particular, mathematical methods such as differential equations and integral calculations provide a better understanding of topics such as electromagnetism and thermodynamics. The Journal of Mathematical Physics defines mathematical physics as "The application of mathematics to physical problems and the development of mathematical methods for physical theories." Physicists must understand and apply mathematical concepts at a level close to that of mathematicians; because a new theoretical model may require mathematical methods that have not yet been discovered. This can

directly contribute to the development of mathematics; as differential calculus was first introduced by Newton to explain physical phenomena. Newton's mechanics exemplifies the use of integral calculus in the study of electricity and magnetism.

Engineering

Engineering stands out as an interdisciplinary field where mathematical models and analyzes form the basis. In project design and development processes, mathematics is used as a fundamental tool in system analysis, material selection and evaluation of system performance. In many engineering branches, especially electrical engineering, mathematical control systems and tools, especially Laplace transforms, are widely preferred to provide and analyze the desired system behavior. During engineering education, students receive intensive training in mathematical disciplines such as calculus, linear algebra, number theories and differential equations. This enables prospective engineers to develop mathematical thinking and problem-solving skills. Especially in some branches such as computer engineering, having mathematical foundations is of critical importance in software development and generating solutions for unknown systems.

Modern engineering practice views mathematics not only as a tool but also as a fundamental component of solution processes. Engineering uses mathematical models and theories to understand physical phenomena and develop new technologies. This causes engineering disciplines, especially basic science-based fields such as mathematical engineering, physical engineering and chemical engineering, to interact more intensively with mathematics. As a result, engineering and mathematics are two disciplines that feed and depend on each other. While engineering applies the theoretical concepts of mathematics to the solution of practical problems, mathematics also encourages the development of new theories and methods in line with the needs coming from engineering. This mutual interaction contributes to the advancement of both fields and paves the way for scientific innovations.

Computer Science

Computer science makes extensive use of mathematics in fundamental concepts such as algorithm design and analysis and complexity theory. Complexity theory provides a mathematical methodology used to calculate the processing capacity and time of an algorithm, which plays a critical role in optimizing the performance of software. Number theory and cryptography form the cornerstones of digital security. In particular, prime numbers and modular arithmetic are fundamental mathematical concepts used in the development of secure data encryption methods. These concepts are vital in ensuring confidentiality and integrity in electronic communications.

Mathematical software has a central place in the applied aspect of computer science. Tools such as Matlab, Mathematica, Maple, Mathcad and Latex enable complex mathematical calculations, graphic drawings and modeling to be carried out easily. In particular, Matlab offers a wide range of uses for various mathematical operations such as matrix operations, functions and graph drawing. The integration of computer science and mathematics is also strengthened by various mathematical theorems and equations that form the basis of today's technology. For example, concepts such as the Pythagorean theorem and the Fourier transform are considered fundamental methods in signal processing and data analysis. Theories such as the Navier-Stokes equations and Shannon's Information Theory provide significant advances in the fields of fluid mechanics and information communication, respectively. In this context, the synergy between computer science and mathematics has a vital role in the advancement of modern science and technology, being critical in solving complex problems and developing new technologies.

Economy

The discipline of economics makes extensive use of mathematical models in microeconomic and macroeconomic analyses. These models are critical for deeply understanding and predicting market behavior and economic growth mechanisms. Statistics and econometrics stand out as fundamental tools in the analysis of economic data and modeling of economic phenomena. These tools enable economic forecasts to be made and policy decisions to be based on scientific data (Ersoy, 2003). It is widely accepted that mathematics plays a central role in socioeconomic development as well as scientific and technological progress. Mathematics has an important place in the fields of science, technology and innovation, which form the basis of the knowledge economy. Applications of mathematics in these areas contribute to economic development and encourage mental development, which helps meet the need for qualified labor in the labor market (Park, 2006; OECD, 2000).

The use of mathematics in economic analysis provides in-depth knowledge about the nature of the economy and allows the development of economic strategies. This makes mathematics an indispensable tool in the development and testing of economic theories. In addition, mathematics has a strategic importance in areas such as ensuring economic growth, the formation of the information society and the realization of high-quality exports (George & Thomaskutty, 2007; Hanushek & Woessmann, 2008; Thornhill et., 2009).

As a result, the integration between mathematics and economics has a fundamental place in the development of economic theories, shaping economic policies and evaluating economic performance. This integration forms the basis of economic progress and socioeconomic development by ensuring that economic research and applications are more effective and efficient.

Biology

It uses mathematics, especially statistical methods, to understand and analyze large data sets obtained in biology, genetics, ecology and many other subfields. In this way, in-depth information about complex biological processes and systems is obtained. Mathematical biology stands out as an interdisciplinary field that covers topics such as population dynamics, epidemiology and evolutionary biology and helps us understand the behavior of biological systems by modeling them. Although biology is essentially an experimental science, it is not limited to laboratory experiments only. It is divided into two main sections: "Experimental Biology" and "Theoretical Biology". Mathematical biology, as part of theoretical biology, refers to a field in which mathematical models, abstractions, and technical analysis are used to understand biological phenomena.

Mathematical biology comes into play when experimental biology is insufficient or field studies are not possible. Simple mathematical models can be used to isolate and explain the basic elements and processes of biological systems. Most problems in the field of biology have been solved with the help of many mathematical techniques, including differential equations, network analysis, group theory, chaos theory, and probability. In particular, processes such as the folding and entanglement of proteins can be modeled using mathematical concepts such as knot theory.

Philosophy

Logic, as one of the basic building blocks of philosophy, analyzes the accuracy and validity of propositions. Mathematical logic makes important contributions to the logical and consistent establishment of philosophical arguments and thought processes. This highlights the contribution of mathematics in philosophy's effort to concretize abstract thought and deepen conceptual analysis.

Throughout history, the connection between philosophy and mathematics has developed based on the solution of problems. Plato's view of geometry as an integral part of philosophy since the ancient Greek period and his writing on the door of the Akademia, "Do not come if you do not know geometry", symbolizes the deep relationship between these disciplines. Pythagoras's use of numbers as a basis for understanding the universe is an early example of the intertwined nature of philosophy with mathematics.

The application of geometry and arithmetic to philosophical problems has expanded the relations between philosophy and science, especially with developments in the field of astronomy. The works of scientists such as Copernicus and Kepler supported the view that the universe was established

according to mathematical order. This has led to the formation of a structure of thought based on mathematical principles in understanding the universe.

Since the Renaissance, thinkers such as Giordano Bruno, Galileo and Descartes have adopted mathematics as a fundamental element in solving philosophical questions. Philosophers such as Leibniz and Spinoza saw mathematics not only as an aid but also as philosophy itself. In the 20th century, this integration between mathematics and philosophy deepened, especially with the work of the Neo-Kantians and the Vienna School. During this period, philosophy and mathematics began to be understood as complementary and intertwined disciplines.

As a result, logic and mathematical methodologies play a central role in philosophy's process of analyzing problems and generating solutions. This deep integration between philosophy and mathematics manifests itself as a fundamental element of the search for science and wisdom at every stage of the history of thought. This highlights the indispensable role of mathematics in the development of our thought processes and understanding of the universe.

Medicine

Deep integration between medicine and mathematics leads to groundbreaking advances in health sciences. Mathematics plays a fundamental role in a variety of fields, from medical imaging to disease modeling, from algorithms and image processing methods that enable clear and meaningful images to revolutionary reconstruction algorithms in the diagnosis and treatment of diseases. Adjusting drug dosage and understanding the behavior of drugs in the body are optimized through mathematical models, increasing both the effectiveness and safety of treatment. Epidemiological models are used to understand the spread of epidemics and plan intervention strategies, while analysis of data from clinical trials allows the development of new treatments and improvement of existing treatment methods. In the fields of genetics and bioinformatics, mathematical models and statistical methods are critical for understanding complex genetic structures and relationships, while the processing and analysis of genomic data enables understanding of diseases on a molecular basis. Disease models simulate the course of various diseases and their response to treatment, making it possible to understand diseases and develop treatment strategies. Treatment methods and surgical plans can be optimized on a patient-by-patient basis with mathematical optimization techniques, paving the way for personalized treatment solutions. This interaction contributes to the development of more effective treatments, a better understanding of diseases and the establishment of health policies, promotes continuous progress in science and health, and offers innovative solutions to improve the quality of human life.

Result and Suggestions

One of the main purposes of mathematics education is to ensure that individuals have the necessary mathematical knowledge and competencies to solve the problems they will encounter in their daily lives and in different fields. In this context, mathematical association ability is considered a critical skill that improves students' understanding, interpretation, and ability to apply mathematical concepts in practice. Mathematical association includes the ability to establish connections between concepts, understand the relationships between different forms of representation, and use mathematics effectively in daily life. This process allows students to develop a comprehensive understanding at theoretical and practical levels and to use mathematics in interdisciplinary contexts.

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2020). Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

Research shows that teaching mathematics by integrating it with other fields increases students' motivation to learn, increases the retention of knowledge and enables them to develop positive attitudes about mathematics. For this reason, it is recommended to adopt interdisciplinary approaches in mathematics teaching and to teach knowledge and skills in various disciplines by associating them with mathematical concepts. In this context, it is of great importance that teachers and educational programs encourage students to think in relation to mathematics and different disciplines and to reconcile their problem-solving

abilities with interdisciplinary situations. This approach will contribute to mathematics education improving not only academic success but also students' skills in solving real-world problems.

This perspective provides a strong foundation for educators and curriculum developers to present mathematics to students in a more meaningful and applicable way. Students' ability to integrate knowledge from various disciplines with mathematical principles will increase both their academic success and practical problem-solving abilities. Adopting this approach could transform mathematics education to help students develop an interdisciplinary skill set that is vital to their future academic and professional success.

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THE EFFECT OF GAME-BASED MATHEMATICS TEACHING ON STUDENT SUCCESS

Ece Aydın[1], Tayfun Tutak[2]

Abstract

This study focuses on how game-based mathematics teaching strategies can strengthen students' relationships with mathematics, increase their motivation, and improve their overall learning experience. The research reveals that methods such as effective use of technology, focusing on student needs, and developing math games that can be applied at home in cooperation with parents allow for more effective implementation of game-based learning approaches. Additionally, it is emphasized that these strategies have significant potential for the education systems of the future. The study was carried out by literature review method, and the positive effects of game-based learning on students were examined in terms of different aspects such as in-depth understanding, increased interest in learning, and the development of cooperation and communication skills. It is expected that this study will contribute to the development of innovative teaching methods in the field of mathematics education and provide a valuable perspective on teaching practice. It is predicted that this approach can be an effective tool in overcoming difficulties and misconceptions encountered in mathematics education, so it is recommended that teachers and education policy makers pay attention to these strategies.

Keywords: Game-Based Mathematics Education, Education System of the Future, Collaboration with Parents.

Introduction

Nowadays, students are turning to more interactive and technology-oriented learning methods compared to traditional teaching methods. In this context, incorporating educational digital games into mathematics teaching can enable students to interact with course materials more effectively (Prensky, 2001). Educational digital games have the potential to facilitate learning by making abstract concepts such as mathematics more concrete and understandable to students (Gee, 2003). This study investigates whether digital game-based learning positively affects students' attitudes, achievements and self-efficacy perceptions towards mathematics lessons. Additionally, the effect of educational digital games on developing students' problem-solving skills and mathematical thinking abilities is also examined (Squire, 2006).

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One of the biggest challenges in mathematics education is to increase students' interest and motivation in the course. Students' negative attitudes and low motivation towards mathematics may negatively affect their academic success. Educational digital games can increase students' interaction with course materials and support the learning process by making mathematics learning more fun and interesting (Barab et al., 2005).

The purpose of this study is to determine how the integration of educational digital games into mathematics teaching affects students' academic achievement, motivation and self-efficacy perceptions. The research was conducted on secondary school students and the participants were divided into control and experimental groups. While mathematics teaching supported by educational digital games was applied to the students in the experimental group, traditional teaching methods were applied to the students in the control group (Öztürk, Aksoy, 2014).

In conclusion, the integration of educational digital games into mathematics teaching can improve students' attitudes and achievements towards mathematics learning. Therefore, educators and instructional designers may consider incorporating educational digital games into lesson plans to enrich students' learning experiences and increase their mathematics achievement. Effective use of educational digital games can support learning processes and improve students' positive perceptions of mathematics lessons (Vygotsky, 1978).

Mathematics can be a subject where students face many challenges. Game-based learning approach can play a very important role in overcoming these difficulties and helping students deal with mathematics more effectively. This article will focus on the effect of the game-based mathematics learning approach on student success.

Purpose of the Research

The purpose of this study is to examine the studies in the literature on game-based mathematics education strategies. In particular, we will focus on how these strategies can strengthen students' relationships with mathematics, increase their motivation, and improve their overall learning experience. In addition, the aims of the research are to develop suggestions on how game-based learning approaches can be effectively applied in the field of mathematics education and to address the potential advantages and challenges of these methods. This study aims to reveal what role game-based mathematics education can play in future education systems and to provide guiding information to educators and policy makers on this subject.

Research Method

In this study, document analysis model, one of the qualitative research methods, was used. The document analysis method is the systematic examination

of existing records or documents as data sources, which includes information about the subjects to be researched, including accessing data for the purpose of the study and analyzing written sources from these data.

Study Group

The sample of this research consists of a series of articles and theses obtained based on certain selection criteria. In this context, studies focusing on issues such as game-based mathematics teaching strategies, students' relationships with mathematics, motivation levels and improvement of learning experiences were primarily examined. Relevant literature was selected to develop an in-depth understanding of innovative educational methods that can impact student learning processes and the applicability of these methods.

Data Collection Tool

In accordance with the purpose of the research, a comprehensive literature review was conducted. In this process, articles and theses containing information about the effects of game-based mathematics teaching on student success, motivation and general learning experiences were examined. The selected documents discuss in detail the current research trends, application examples and potential impacts on the subject, thus creating a rich data pool to answer research questions. This data collection process was meticulously designed to increase the reliability and validity of the research, so that the findings can make significant contributions to the field of game-based mathematics education.

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education

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Game-Based Mathematics Learning and Student Achievement

Game-based mathematics learning has been shown to have a positive impact on student achievement through a series of studies and experiments. These effects can be summarized as follows:

- **In-Depth Understanding**: Games provide students with the opportunity to relate abstract mathematical concepts to concrete situations (Young et al., 2012). This can help students understand topics more deeply.
- **Increased Interest in Learning**: Games make mathematics-related subjects more interesting and fun (Hamari et al., 2016). This allows students to have a more positive relationship with mathematics and to invest more effort in this field.
- **Development of Collaboration and Communication Skills**: Games often encourage group work (Plass et al., 2015). This can help students improve their ability to collaborate with each other and solve math problems together.
- **Strengthening Students' Relationship with Mathematics**: Game-based mathematics learning offers students the opportunity to relate abstract mathematical concepts to their daily lives (Squire, 2006). This strengthens the connection with mathematics and allows students to consider topics in a more realistic context. For example, solving mathematical problems through games can give students the ability to connect to real-world applications.
- **Adaptability of Games to Individual Learning**: Game-based mathematics learning offers a flexible structure that can take into account students' individual learning styles and speeds (Van Eck, 2006). Games allow students to progress at their own pace and customize difficulty levels. This can help each student gain the ability to manage and control their own learning process.
- **The Role of Games in Encouraging Student Participation**: Games can increase students' interest and participation in learning (Gee, 2003). Interactive games allow students to interact with mathematics, and this interaction can help students understand the topics more effectively. Tasks and puzzles presented to students through games can improve their search for solutions to mathematical problems.
- **Long-Term Effects of Game-Based Learning**: Game-based mathematics learning can increase students' motivation levels regarding mathematics not only in the short term but also in the long term (Wouters

et al., 2013). Students can also use the problem-solving skills and mathematical thinking skills they acquire through games in their daily lives. This contributes to the development of an understanding that learning about mathematics is valid not only in the classroom but also in other areas of life.

- **Role of Curriculum and Educational Policies Regarding Game-Based Mathematics Learning**: Game-based mathematics learning should be effectively included in the design of curricula and educational policies. Curriculum developers should strive to equip students with mathematical skills through various games by integrating the game-based learning approach into mathematics courses. At the same time, educational policies should support such learning methods and provide teachers with the necessary tools to use this approach (Clark et al., 2016).
- **The Role of Technology and Game-Based Educational Tools**: Technology can be a powerful tool to support game-based mathematics learning processes (Sitzmann, 2011). Technological tools such as virtual reality, augmented reality and interactive simulations offer students the opportunity to explore abstract mathematical concepts in a more concrete and interactive way. These technological tools can provide students with the ability to solve real-world problems in a virtual environment.
- **Increasing Diversity and Participation in Education**: Game-based mathematics learning has the feature of appealing to student diversity and different learning styles (Steinkuehler & Duncan, 2008). This approach could reduce biases about mathematics and more equitably distribute educational opportunities among students. Promoting diversity in education is an important step towards closing gaps in mathematics achievement based on factors such as gender, ethnicity, and socioeconomic status.
- **Sustainability and Evaluation of Game-Based Mathematics Education**: For the sustainability of game-based mathematics learning strategies, it is important to evaluate the effects of these methods. Educators must develop new methods and measurement tools to evaluate student achievement. It is also critical to provide regular feedback to monitor student progress and evaluate the long-term effects of game-based mathematics learning strategies.
- **Teacher Training and Professional Development**: In order to effectively implement game-based mathematics learning strategies, it is important for teachers to receive training appropriate to this approach. Teacher training can enable them to understand, integrate and use game-based learning methods effectively in their classrooms. It is also important to

encourage the sharing of experience among teachers and disseminate best practices.

- **Increasing Family and Community Participation**: Game-based mathematics learning strategies should also include the participation of families and society. Families can use game-based mathematics activities at home to support students' relationships with mathematics. Schools and community centers can strengthen students' engagement with mathematics by organizing activities that include these strategies.
- **Various Learning Materials and Games**: Various learning materials and games should be used to enrich game-based mathematics learning strategies and appeal to a wider audience of students. Games with different difficulty levels allow students to adapt to different ability levels. This variety can help each student find a game that suits their learning needs.
- **National and International Collaborations**: National and international collaborations and shared resources are important for the successful implementation of game-based mathematics learning strategies. Sharing experiences between education systems in different countries allows the identification of best practices and the effective implementation of these strategies in each system.
- **Sustainable Financing and Resource Provision**: Financial support and resources must be provided for the sustainability of game-based mathematics learning strategies. This should include allocating the necessary budget for teacher training, games and technological tools. Allocating resources in education budgets for game-based mathematics learning helps these strategies reach a wider audience of students.
- **Adaptive Games and Applications Focusing on Individual Needs**: The use of adaptive games and applications is of great importance for the advanced development of game-based mathematics learning strategies. These applications can be designed to adapt to students' individual learning needs. Adaptive games, which can automatically adjust difficulty levels according to students' levels, allow each student to progress at their own pace and identify their strengths and weaknesses.
- **Development of Virtual Learning Environments**: Virtual learning environments can provide an interactive and student-centered experience that supports game-based mathematics learning strategies. Virtual classrooms can give students the chance to experience and apply mathematical concepts in the virtual world. Such environments allow students to learn mathematics in depth by providing them with the

opportunity to concretize, experience and explore mathematics-related subjects.

- **Expanding Game-Based Learning in Different Branches**: Game-based learning strategies may not be limited to mathematics courses only. The use of game-based learning methods in different lessons and subjects allows students to acquire versatile skills and develop interests in various areas of knowledge. For example, game-based learning strategies can be effectively applied in courses such as language arts, science, and social sciences.
- **Relationship between Game-Based Learning and Student Health**: With developing technology, especially through mobile games, it is important to evaluate game-based applications in terms of student health in order to support students' learning processes. A healthy balance should be established by taking into account factors such as students' screen time, content of games and interaction styles.
- **Strengthening Educational Research**: More investment in educational research is necessary to better understand the effects of game-based mathematics learning strategies and to continuously improve these strategies. Scientific research conducted to understand the effects of effective teaching strategies, student achievements and learning processes can pave the way for developments based on solid foundations in this field.
- **Global Collaboration and Sharing Platforms**: Global collaboration and sharing platforms can be created to increase the impact of game-based mathematics learning strategies and disseminate these methods to a wider audience. Education professionals, teachers, researchers and students can share their experiences, discuss best practices and learn from each other on these platforms. Such platforms can contribute to the development and implementation of game-based mathematics learning strategies at a universal level.
- **Development of Measurement and Evaluation Methods in Game-Based Mathematics Education**: It is important to develop appropriate measurement and evaluation methods to evaluate the effects of game-based mathematics learning strategies. More specialized assessment tools that focus on measuring student performance, problem-solving skills, and in-depth meaning rather than traditional exams may more accurately reflect the successes of game-based learning strategies.
- **Teacher and Student Feedback Mechanisms for Game-Based Mathematics Education**: In game-based mathematics education processes, feedback mechanisms need to be developed in order to increase

the interaction between teachers and students. These mechanisms can help track student progress, provide students with rapid and customized feedback, and help students understand their mathematics strengths and weaknesses.

- **Awareness Raising Studies to Change Social Perception**: Game-based mathematics education should still include awareness raising activities to change the general perception of traditional teaching methods. Raising awareness throughout society that game-based mathematics learning strategies are an effective learning method and that students can learn more effectively with these methods can help attract more support for these strategies.
- **Using Game-Based Mathematics Education for Social Justice and Equality**: Game-based mathematics education can be used as an effective tool to achieve social justice and equality goals. This strategy can provide equal opportunities to students from different socioeconomic levels and cultural backgrounds. Game-based mathematics education can be planned more strategically to reduce educational inequities and close achievement gaps among students.
- **Data Analytics and Student Progress Tracking**: Data analytics can be used to better understand the impact of game-based mathematics learning strategies and track student progress. This allows detailed data on student performance to be collected and analyzed and to identify student-specific learning pathways. Data analytics allows for more personalization of the learning process by identifying students' strengths and weaknesses.
- **Development of Virtual Reality and Augmented Reality Applications**: Thanks to the rapid development of technology, virtual reality (VR) and augmented reality (AR) applications can be used to support game-based mathematics learning strategies. These applications can offer students the opportunity to experience mathematical concepts in a visual and interactive way. VR and AR can increase students' understanding by making abstract mathematical concepts concrete.
- **Artificial Intelligence and Adaptive Learning Systems in Game-Based Education**: Artificial intelligence (AI) and adaptive learning systems can strengthen game-based education strategies that respond more effectively to students' individual needs. Artificial intelligence can deliver customized learning materials by analyzing student performance. This allows students to have a more effective learning experience, taking into account their learning pace and preferences.
- **Parent Education and Use of Game-Based Mathematics Applications in the Family**: Parents can be encouraged to use game-based mathematics

applications in the family to support students' mathematics learning. Parent education programs can explain game-based learning strategies to families and teach them how to implement this approach at home. This can strengthen students' connection to mathematics and create a positive learning environment within the family.

- **Integration of Game-Based Mathematics Education with the Business World**: Game-based mathematics education strategies can help students gain skills appropriate to the needs of the business world. By collaborating with the business world, special game-based training programs can be developed to provide students with the mathematical competencies necessary to develop business skills.
- **Financial Accessibility of Game-Based Mathematics Education**: Efforts should be made to increase the financial accessibility of game-based mathematics education strategies. Providing educational materials and games at affordable or free prices can provide equal opportunities to students from different socioeconomic levels. It is important to overcome financial barriers to reduce educational inequalities and provide a quality mathematics education for every student.
- **Integration of Game-Based Mathematics Education and Social Skills**: Game-based mathematics education strategies should support not only mathematical skills but also social skills. Social skills such as collaboration, communication, problem solving and teamwork can provide students with skills that will be useful not only in math classes but also throughout their lives.
- **Game Materials and Scenarios that Reflect Diversity in Education**: Game-based mathematics education materials should appeal to a variety of students from different cultural backgrounds and experiences. Game scenarios should offer students a variety of perspectives and include examples from different cultures. This can help strengthen students' engagement with mathematics.
- **Game-Based Mathematics Education and Science, Technology, Engineering, and Mathematics (STEM) Integration**: Game-based mathematics education strategies can integrate the fields of science, technology, engineering, and mathematics (STEM). This integration may offer an approach to equipping students with the versatile skills necessary to solve real-world problems. STEM-focused games can give students an interdisciplinary perspective and allow them to approach problems holistically.
- **Developing Game-Based Mathematics Education with Student Feedback**: Student feedback is a valuable resource for continually

improving game-based mathematics education strategies. Getting feedback on how students experience games, which topics are difficult, and what types of learning materials are more effective can help instructional designers and teachers develop more effective, student-centered strategies.

- **Focus of Game-Based Mathematics Education on Teacher Training**: It is important for teachers to receive special training so that they can effectively implement game-based mathematics education strategies. Teacher training programs can guide teachers on how to integrate game-based learning strategies, track student progress, and use games effectively in teaching.
- **Use of Interactive Methods in Game-Based Mathematics Education**: Game-based mathematics education strategies can make the learning process more participatory by providing students with interactive experiences. Interactive learning methods that allow students to play an active role through games, solve questions, and manage their own learning process can help them better understand mathematics-related concepts.
- **Game-Based Mathematics Education Increases Student Motivation**: Games enable students to establish an emotional connection to the learning process. Game-based mathematics education can increase students' motivation because games often include reward systems, leveling up, competition, and a sense of achievement. These elements can engage students more positively with mathematics and increase their interest in learning.
- **Game-Based Mathematics Education Promotes Social Interaction**: Games can encourage social interaction among students. Group games or multiplayer games can enable students to collaborate with each other, solve problems together, and improve communication skills. This allows students to explore math-related concepts together.
- **Game-Based Mathematics Education Increases Error Tolerance**: Games give students the opportunity to make mistakes and learn from these mistakes. Mistakes in math-related subjects can become less threatening through games. Thanks to games, students can experience the process of learning from mistakes by using the trial-and-error method. This can increase confidence and error tolerance in mathematics.
- **Game-Based Mathematics Education Supports Creativity**: Games can provide students with creative thinking and problem-solving skills. Games often require solving complex problems and allow students to develop a variety of strategies. Creative thinking is an important feature

related to the ability to address mathematical problems from different perspectives and find flexible solutions.

- **Game-Based Mathematics Education Promotes Concretization and Application**: Games can provide opportunities to concretize and apply abstract mathematical concepts. Games that allow students to use mathematical concepts in real-world contexts can help them understand how the knowledge learned can be used in daily life.
- **Use of Technology and Digital Games in Game-Based Mathematics Education**: The rapid development of technology has facilitated the use of digital games for game-based mathematics education. It can provide students with interactive and fun mathematics experiences through computer games, tablet applications or online platforms. This also helps students develop their skills in using technology effectively.
- **Games Customizable to Student Needs**: Game-based mathematics education strategies can be customized to meet students' individual needs. Games that can be adapted to students' levels and learning styles allow each student to progress at their own pace and identify their strengths and weaknesses. This allows students to have a personalized learning experience.
- **Real-Time Feedback in Game-Based Mathematics Education**: Digital games have the potential to provide real-time feedback to students. Students can immediately realize their mistakes and have a chance to learn from these mistakes. Real-time feedback can help students' correct misconceptions, understand missing material, and see their success immediately.
- **Math Games That Can Be Used at Home in Collaboration with Parents**: Digital games can be turned into interactive math games that students can use at home with their families. This allows parents to support students' engagement with mathematics and enrich the learning experience at home. Games that can be used collaboratively with parents can help students gain greater confidence in math-related topics.
- **Integration of Game-Based Mathematics Education with Social Media and Online Communities**: Game-based mathematics education strategies can allow students to interact with each other through social media and online communities. Students can ask math questions, share strategies, and support each other. This can enable students to consider mathematics-related topics from a broader perspective.

Result and Suggestions

The future of mathematics education depends on the development of innovative approaches that strengthen students' relationships with the course, increase their motivation and enrich their learning experiences. In this context, game-based mathematics teaching strategies have significant potential in the field of education. Rawansyah et al.'s (2021) study reveals that the development of serious mathematics games can increase student interest and also improve competitiveness and numerical abilities. Games make mathematics interesting for students thanks to their reward systems, which increases their interest in the learning process (Rawansyah et al., 2021). Yuliana Sinaga et al.'s (2023) research shows that game-based mathematics teaching materials contribute to students' understanding of mathematics subjects more effectively, improving their problem-solving skills and socialization in the classroom. This study emphasizes that games, especially 'math duel' and 'ice breaking', improve classroom dynamics and significantly increase students' interest and motivation in lessons (Yuliana Sinaga et al., 2024).

In light of these findings, there is a need for teachers and education policy makers to further integrate game-based strategies in mathematics teaching. Game-based mathematics teaching must play a central role in the future of our education systems, with the aim of strengthening students' relationships with mathematics, increasing their motivation and improving their learning experiences.

As a result, the integration of game-based learning approaches in mathematics education has the potential to increase students' interest and motivation in lessons. These approaches can improve numerical skills as well as critical thinking skills such as problem solving, collaboration and communication, by allowing students to understand mathematical concepts in a more concrete and interactive way. Educators and policymakers supporting and encouraging these innovative teaching strategies will allow students to develop 21st century skills (Rawansyah et al., 2021; Yuliana Sinaga et al., 2024).

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NECESSITY AND IMPORTANCE OF MATHEMATICS EDUCATION

Esra Cilvezkaya[1]

Abstract

In today's world, rapidly shaped by technological advancements, mathematics education plays a critical role in developing individuals' fundamental abilities. This study examines why mathematics education is so crucial and its impact on society. Through a detailed examination of the existing literature, the research highlights how mathematics education strengthens individuals' problem-solving (Costa, 2005), analytical thinking (Peter, 2011), and decision-making capabilities. It also emphasizes that these skills contribute not only to academic success but also enable individuals to cope with challenges they will encounter in their daily lives (Magnus, 1954) and in their long-term career trajectories. The study documents the contribution of mathematics education to societal and economic development (Ore, 1944) and argues that investment in mathematics learning is vital for a country's overall progress (Akkoyunlu, 1995; Peter, 2011). In this context, it delivers a clear message on the need to strengthen educational systems and provide accessible mathematics education for everyone.

Keywords*: Mathematics Teaching, Importance of Mathematics Education, Problem Solving, Analytical Thinking.*

Introduction

Mathematics has been one of the cornerstones of our knowledge and civilization throughout human history. This universal language has had a profound impact on the fields of engineering and science, as well as more abstract disciplines such as art and music. While mathematics allows us to understand the structural beauty and complexity of the universe, it also helps us develop the analytical skills necessary to cope with the challenges of daily life (Magnus, 1954). In this context, mathematics education plays a critical role in finding solutions to the most important challenges of our age and ensuring social progress.

Today, the innovations and challenges brought by technological advances have further increased the importance of mathematics education. In this period called the information age, mathematical thinking and problem-solving skills are of vital importance in solving practical problems that individuals encounter in daily life and in reaching logical conclusions when making complex

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decisions. In particular, researchers such as Peter (2011) and Akkoyunlu (1995) have pointed out how mathematics education improves individuals' analytical thinking, problem solving and critical evaluation abilities and how it can increase the general education level of society.

However, mathematics education is also of great importance in preparing students for their future careers and providing them with interdisciplinary thinking skills. It is an indispensable tool for students of mathematics, science and engineering, as well as students of social sciences and humanities. This offers students a broad perspective on analyzing and solving the problems they will encounter (Costa, 2005; Ore, 1944).

The research highlights the overall importance of mathematics education and its impact on society. This study aims to examine in detail how mathematics education plays a fundamental role in the lifelong learning processes of individuals and the general progress of society by considering the existing literature from a broad perspective.

Purpose of the Research

The aim of this study is to understand and explain the effect of mathematics education on individuals' analytical thinking, problem solving and critical evaluation abilities. In particular, it aims to examine in depth the contributions of mathematics education to social and economic development along with the rapid change of technological advances. By covering a wide range of existing literature, the research aims to reveal how learning mathematics contributes to individuals' ability to cope with the difficulties they will encounter in their daily lives and long-term career goals. It will also examine how mathematics education makes a fundamental contribution to the development of a country and how education systems can be strengthened in this area.

Research Method

In this study, the impact of mathematics education on individuals and its contributions to social and economic development were examined. The research used a literature review method to analyze the existing academic literature in depth. In this process, both printed and digital resources were scanned and important findings, theories and discussions regarding mathematics education were identified.

Study Group

The sample of the research consisted of articles and theses written on mathematics education obtained from the sources of the Council of Higher Education Thesis Center (YÖK TEZ) and the National Academic Network and Information Center (ULAKBİM). These studies were selected according to the determined criteria.

Data Collection Tool

In the study, literature on mathematics education was collected from YÖK TEZ and ULAKBİM databases with a systematic scanning method. This process was carried out carefully in accordance with the purpose of the research.

Analysis of Data

The collected data were examined using the descriptive analysis method. This approach allowed the data to be rearranged in accordance with the research questions and evaluated from different perspectives (Şimşek and Yıldırım, 2003).

Difficulties in Learning Mathematics

Mathematics education emerges as a global challenge; It leaves significant impacts on students, teachers and education systems. At the root of these difficulties are factors such as curriculum changes, teaching methods, teachers' competence in the subject and lack of materials. In particular, the abstract content of mathematics courses makes it difficult for students to make associations with concrete examples, and this creates obstacles in the learning process (İşleyen and Işık, 2003).

Another important issue related to mathematics learning is mathematics anxiety. This anxiety refers to the anxiety, fear and nervousness that students experience when faced with mathematics-related situations. Sources of math anxiety include factors such as exam stress, incorrect learning methods, and peer or family pressure. Students with high levels of anxiety generally have more difficulty in solving mathematical problems, and this negatively affects their motivation to learn (Richardson & Suinn, 1972; Dreger & Aitken, 1957).

Additionally, measurement and evaluation methods used in education may lead students to superficial learning and memorization. This approach can hinder the development of mathematical thinking skills and prevent students from understanding mathematical subjects in depth (Fennema and Sherman, 1976).

Contributions of Mathematics to Daily Life

Mathematics has an indispensable role in many areas of life. Mathematics is used in a wide range of areas, from daily decision-making processes to financial planning, from scientific research to engineering problems. Mathematical thinking improves individuals' abilities to analyze events, solve complex problems and reach logical conclusions. These skills are critical for individuals to cope with the challenges they face in both their personal and professional lives.

Mathematics education also allows individuals to develop critical thinking, creative problem solving and effective communication skills. These skills are

essential to succeed in today's rapidly changing and knowledge-based society. In particular, mathematics education plays an important role in raising the general education level of the society and supporting economic development (Magnus, 1954; Akkoyunlu, 1995).

Learning mathematics enables individuals from all segments of society to become compatible with technological innovations and to use these innovations effectively in their daily lives. Mathematics should therefore be viewed not only as an academic discipline, but also as a fundamental skill that supports individuals to achieve success in all areas of life.

Result

This study focuses on mathematics education and comprehensively discusses the difficulties faced by students and the contributions of mathematics to the daily lives of individuals. Findings indicate that difficulties in learning mathematics do not arise solely from individual learning styles; It also shows that it is affected by the structure of education systems, the competence of teachers and the quality of teaching materials used. These findings emphasize the complex nature of mathematics education and the multidimensional factors affecting student success (İşleyen & Işık, 2003; Richardson & Suinn, 1972).

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2020). Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

Additionally, the study points out the important role that mathematics plays in developing individuals' basic life skills such as critical thinking, problem

solving and decision making. It has been determined that mathematics education is a critical factor in raising individuals who can keep up with technological developments, produce innovative solutions and analyze complex situations (Magnus, 1954; Akkoyunlu, 1995).

As a result, mathematics education is a fundamental field not only for academic success, but also for improving the skills of individuals to cope with the challenges they may encounter in daily life. Every investment made in education systems contributes to increasing the general education level of society and the quality of life of individuals. Therefore, studies on mathematics education and recommendations put into practice can significantly contribute to the development of future generations at both individual and social levels.

Suggestions

1. Teacher Training: Teachers must have the necessary skills to overcome the challenges encountered in teaching mathematics. Therefore, teacher training programs should include more topics such as mathematics teaching methods, student motivation and mathematics anxiety.

2. Curriculum Development: Curriculum should be designed to develop students' mathematical thinking and problem-solving skills. This can make mathematics more meaningful and engaging by providing students with practical examples through which they can relate mathematical concepts to daily life.

3. Learning Materials: Educational materials should suit the different learning styles of students and provide interactive learning opportunities. In particular, digital learning tools and apps can support students' mathematics learning.

4. Family Participation: In order for students to be successful in learning mathematics, families should be encouraged to actively participate in the process. Families should have access to the resources and information necessary to support their children's mathematics learning.

5. Assessment Methods: Assessment and evaluation methods should be developed to evaluate students' mathematical thinking and problem-solving skills fairly and effectively. This encourages a skills-focused rather than exam-focused approach.

These recommendations can help overcome challenges in mathematics education and improve students' mathematical skills. Additionally, it can contribute to increasing the positive role of mathematics in individuals' daily lives.

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A LOOK AT THE PLACE OF MULTIPLE REPRESENTATIONS IN MATHEMATICS EDUCATION

Aybüke Fidan[1], Ünal İç[2]

Abstract

In this research, it is aimed to examine in depth the role of multiple representations in mathematics education, which develops with the changing world conditions. In this study, the definition of multiple representations, their various models and their place in mathematics education are examined by examining the existing literature from a broad perspective. In the research, literature on multiple representations was collected from YÖK TEZ and ULAKBİM databases with a systematic scanning method. Data were collected throughout the study. In the analysis of the collected data, it was analyzed using the descriptive analysis method. This study documents the contribution of multiple representations in mathematics education. Some suggestions have also been made to researchers.

Key Words: Mathematics education, Multiple representations, The importance of multiple representations, Representation

Introduction

Rapid changes in science and technology, the ever-changing needs of society, and innovations and developments in learning and teaching theories and approaches have directly affected the roles expected from individuals (MEB, 2018). Changing social conditions have revealed significant changes in thought in mathematics education. One of the issues that emerged with these changes in thought and attracted the attention of mathematics education researchers is multiple representations (Karahan, 2024). Multiple representation is to emphasize the various aspects of these complex concepts by providing multiple concretization opportunities for concepts (Boyun, 2024). Multiple representation in mathematics education means that a problem situation or concept depends on the creativity of the person; It is expressed in multiple and different ways such as pictures, symbols, signs, words, graphs, tables, dynamic representations (Can, 2014).

Multiple representations and translating multiple representations into each other is an important skill that needs to be developed for students to become more competent in mathematics education (Mainali, 2021). It can be said that

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the role of multiple representations, which have many benefits for students such as assimilating mathematics, concretizing it, making connections, and providing meaningful and permanent learning, has developed considerably in mathematics education in recent years. Multiple representations have been the subject of research since the early 20th century, and the National Committee on Mathematical Requirements of the Mathematics Association of America explained the place of different representations in the fields of algebra and geometric problem solving. In our country, with constructivist education that has become widespread since 2005, the importance of multiple representations in mathematics education has begun to be emphasized (Baloğlu-Demir, 2022). Within the specific objectives of the 2018 mathematics course curriculum prepared by the Ministry of National Education, it was stated that concepts can be expressed with different forms of representation and attention was drawn to multiple representations (MEB, 2018). In the 2024 secondary school mathematics curriculum, the "mathematical representation" skill is included among the five field skills aimed to be developed (MEB, 2024). Although teaching programs have changed over the years, it can be seen that the emphasis on multiple representations in these programs continues to increase.

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2020). Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

This research highlights the definition, models, and general importance of multiple representations. The study aims to examine in detail how important

multiple representations play in mathematics education by scanning the existing literature from a broad perspective.

Purpose of the Research

The aim of this study is to recognize multiple representations, understand and explain the impact of multiple representations in mathematics education.

Research Method

In this study, multiple representations and the role and contributions of multiple representations in mathematics education were examined. The research uses a literature review method to analyze existing academic literature in depth. In this process, both digital and print sources were scanned and important findings, theories and debates regarding multiple representations were identified.

Study Group

The study group of the research consisted of articles and theses written on multiple representations obtained from the sources of the Council of Higher Education Thesis Center (YÖK TEZ) and the National Academic Network and Information Center (ULAKBİM). These studies were selected according to the determined criteria.

Data Collection Tool

In the research, literature on multiple representations was collected from YÖK TEZ and ULAKBİM databases with a systematic scanning method. This process was carried out in detail in accordance with the purpose of the research.

Analysis of Data

The collected data was analyzed using the descriptive analysis method. This approach allowed the data to be rearranged in accordance with the research questions and evaluated from different perspectives (Şimşek and Yıldırım, 2003).

Multiple Representations and Models

Representation is defined as “acting on behalf of someone or a group” (Turkish Language Association, 2023). In terms of mathematics education, the word representation can be explained as the tools needed to process mathematical facts in the mind and convey them to another person (Karahan, 2024).

Multiple representations are tools that enable the same concept to be encountered more than once and express this concept again and again in various ways such as verbal, graphical, numerical and mathematical (Karahan, 2024). Multiple representations can generally be discussed under two subheadings: internal representations and external representations (İlhan, 2019). While internal representations are images that appear in students’ minds of a concept

or idea, external representations are various representations used to concretize concepts or problem situations (Can, 2014). Internal representations cannot be observed directly, but inferences can be made based on external behaviors. Shapes, information and images formed in the mind are examples of internal representations, while external representations express embodied, observable behaviors. Words, graphs, pictures, equations, or manipulatives are examples of external representations. There is also an interaction between internal and external representations. External representations and internal representations shape each other's creation process (Gürmen, 2024).

Lesh, Post and Behr's (1987) model, which includes five different representations, is one of the most widely used multiple representation models among many models found in the literature (Gürmen, 2024). According to this model, representation types can be examined under five headings.

1. Manipulative models (concrete objects) are physical objects such as legos, fraction sticks, and base ten blocks that are used to explore and describe mathematical concepts (Van De Walle, Karp & Bay-Williams, 2019). The use of concrete objects to represent knowledge facilitates learning, allows the use of more than one sense organ in learning environments, and allows for permanent and meaningful learning. (Thoughtless, 2019)

2. Pictures and diagrams can be used to solve a problem using number lines, modeling areas, etc. They are tools used to explain with figures (Baloğlu-Demir, 2022). It is seen as a way that can be used to concretize abstract mathematical knowledge and to represent knowledge in order to provide permanent learning by directing students' focus and attention to mathematical knowledge (Düşünsel, 2019).

3. Verbal symbols (spoken language or verbal language) are needed to represent mathematical knowledge in spoken language so that students can understand the basic structure of mathematics and do mathematics in general. Students establish effective mathematical communication by adopting the language of mathematics. However, in order to avoid memorization, spoken language representation should be supported by blending it with various representation methods (Düşünsel, 2019).

4. Written symbols (symbolic language) are sentences and expressions specific to mathematics. (Baloğlu-Demir, 2022). In order for students not to have difficulty in using the language of mathematics and understanding the nature of mathematics correctly, symbols should be taught to students correctly and completely. Students should be made aware that mathematical knowledge can be represented with symbols (Düşünsel, 2019).

5. Real-life situation representation ensures that students are frequently compared to real-life situations within the scope of mathematics lessons, in

order to make students realize that mathematics is intertwined with life and the importance of knowing mathematics in order to survive. (Thoughtless, 2019).

The Role of Multiple Representations in Mathematics Education

Understanding, using and communicating mathematical concepts effectively is closely linked to students' ability to switch between representations and representations (Bosse, AduGyamfi & Cheetham, 2011). Multiple representations support students in connecting mathematical concepts with each other. For example, when a mathematical problem is given verbally, students' ability to visualize this problem by turning it into a graph or table can help them understand the problem better (Boyun, 2024). Multiple representations can contribute positively to students' conceptual and systemic learning and enable higher-level learning to be achieved. It is also considered necessary to raise individuals who love mathematics, understand the nature of mathematics, and realize that mathematics is a part of life. (Thoughtless, 2019). Learning environments that include multi-media and multiple representations have a high probability of attracting students' attention and make a significant contribution to promoting effective learning conditions (Boyun, 2024).

Dufour-Janver, Bednarz and Belanger (1987) stated various reasons for using representations in mathematics education. Some of these are:

- Representations are an indispensable part of mathematics.
- Representations are multiple instantiations of a concept.
- Representations are used to address specific difficulties.
- Representations aim to make mathematics more attractive and interesting (Mainali, 2021).

Result

This research focused on multiple representations and comprehensively discussed the basic information about multiple representations and their contributions to education.

Multiple representations have a very important place in structuring mathematical concepts, developing problem-solving skills and representing real-life situations with mathematical expressions. For this reason, multiple representations are seen as a skill that must be acquired in mathematics education and contribute to the acquisition of skills such as communication, reasoning and association (Şaşkan, 2023).

As a result, multiple representations can enable students to embrace mathematical concepts, concretize them, express them in different ways, and relate these different shapes to each other. Multiple representations can also improve students' problem-solving skills and reasoning powers, as they will enable students to develop more than one solution when used. It can achieve

permanent learning. In addition, multiple representations may affect students' academic achievement as well as their attitude towards the course. Since students will be active during the lesson, the lesson may become more interesting and the student's motivation may increase.

Considering this information, research on multiple representations and suggestions to be put into practice may contribute to the development of mathematics education in the future.

Suggestions

Some recommendations can be made based on this study and the findings of the sources examined in this study.

- The importance of representations can be increased in the curriculum prepared by the Ministry of National Education and different types of representations can be given more space in textbooks.
- During the teaching process, teachers can use more than one type of representation and students can be encouraged to use more than one type of representation. Additionally, students can be helped to notice the relationships between representations.
- During the evaluation process, methods can be used to evaluate students' ability to reach solutions in various ways using multiple representations instead of a single way.
- Teachers can be provided with informative in-service training on multiple representations and pilot practices can be included as long as resources allow.

These suggestions may help multiple representations progress more effectively in mathematics education. It can also contribute to raising awareness about multiple representations.

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THE PLACE AND IMPORTANCE OF CONCRETE MATERIALS IN MATHEMATICS EDUCATION

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Abstract

It can be said that concrete materials have an extremely important place in teaching mathematics, which is an abstract science. In this study, the benefits and place of concrete materials used in mathematics education are mentioned and some frequently used concrete materials are briefly examined. The research also mentioned that concrete materials can be diversified. For these purposes, the research was conducted by literature review method. The data of the research were collected by a systematic scanning method from the literature, YÖK THESIS and ULAKBİM databases. As a result of the research, it was determined that the use of concrete materials, especially at the primary education level, would be beneficial for mathematics learning. In addition, although it has disadvantages, it has been determined that it has more advantages and supports the student in a positive sense, contributing to the student's understanding of mathematical concepts more clearly.

Key Words: Mathematics Education, Mathematics Teaching, Concrete Materials

Inroduction

Mathematics is a science that develops mental thinking skills with a unique language and systematics consisting of abstract concepts. This abstract structure of mathematics is very difficult to learn and teach, especially for primary school students. For this reason, learning environments that include different types of representation such as symbols, concrete objects, pictures and diagrams should be created in mathematics teaching and education (Yazlık, 2018). In this context, Kelly (2006), as a result of a study he conducted on the use of concrete objects, stated that starting to use concrete objects in mathematics teaching, especially in the primary school years, will be very effective on students' learning and problem-solving skills. Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). He emphasized

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that the use of concrete objects in mathematics teaching, especially in primary school years, will have a positive impact on students' learning in the coming years (Kutluca & Akın, 2013).

In fact, many mathematics educators confirm that materials play an important role in the development of students' mathematical mindsets (Çiftçi & Yıldız & Bozkurt, 2015). In the mathematics curriculum that was reorganized in 2005 and 2013 in our country, teachers and students are encouraged to use concrete materials while conducting mathematics lessons (MEB, 2005, 2013).

Materials, whose importance in mathematics education cannot be ignored, can be defined as objects arranged to concretize abstract mathematical concepts and make them more understandable (Çiftçi & Yıldız & Bozkurt, 2015). Concrete materials can be real-world objects or objects specifically designed to embody mathematical concepts. It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). Examples of these objects include objects used in daily life such as beads, buttons, and beans, as well as objects designed for mathematics teaching such as counting blocks, fraction sets, geometry sticks, tangrams and symmetry mirrors (Yazlık, 2018).

Considering the education calendar given in our country; It is known that an individual who starts his/her education life learns/taught mathematics for an average of 12 years. However, we cannot say that an individual who has been exposed to mathematics for as many years as mentioned has learned mathematics fully. Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2022). We can only say that it is capable of basic concepts and four operations. However, gaining mathematical thinking skills is a very important issue. Fully conveying this issue will be possible by adding concrete mathematical materials to the education curriculum in our country and using them effectively. In this way, mathematics, which is essential throughout life, will be more inherited and more understandable (Bozkurt & Akalın, 2010).

Purpose of the Research

The aim of this study is to examine the existing literature in a wide range and to reveal how we can facilitate the abstract, difficult to understand part of mathematics by using concrete materials and what concrete materials are.

Research Method

In this study, literature review method was used as a method. During this study, both digital and printed sources were scanned and important findings, theories and discussions regarding concrete materials were identified.

Study Group

The study group of the research consisted of articles and theses written on mathematics education and concrete materials obtained from the sources of the Council of Higher Education Thesis Center (YÖK TEZ) and the National Academic Network and Information Center (ULAKBİM). These studies were selected according to the determined criteria.

Data Collection Tool

In the study, information about concrete materials in mathematics education was collected by a systematic scanning method from the literature, YÖK THESIS and ULAKBİM databases.

Analysis of Data

The collected data were examined using the descriptive analysis method. This approach allowed the data to be rearranged in accordance with the research questions and evaluated from different perspectives (Şimşek and Yıldırım, 2003).

Benefits of Concrete Materials Used in Mathematics Education

There are many benefits provided by concrete materials used in mathematics teaching. These:

- It helps students reason mathematically and make observations between conceptual relationships.
- When the teacher uses concrete materials in the lesson, the student's interest and attitude towards the lesson can change positively.
- Students can observe different patterns in the designed mathematical concrete materials.
- It can contribute to the positive change in students' multiplicative thinking abilities, which are effective in their reasoning.
- It can be used to make sense of many geometric patterns and to convey and teach abstract concepts effectively.
- Can observe the connections between geometric objects.
- It allows the development of the mathematical language preferred by students and the representation of mathematical knowledge by transferring it to different branches.
- It creates a basis for students to positively develop their spatial visualization skills.

- It allows students to take their mental rotation skills to an advanced level (Demir, 2019).

In this context, the use of concrete materials can positively change students' perspectives in mathematics education, especially in the field of geometry, which is one of the sub-branches of mathematics, and reduce the problem situation to a simpler level.

Some Concrete Materials Used in Mathematics Education

In mathematics, concrete materials are considered as objects that we can touch and move from one place to another. Mathematical definitions are preferred due to a clear understanding of the theorems (Hacıömeroğlu & Apaydın, 2009). In this study, a few materials used in mathematics are briefly mentioned.

Tangram

Tangram is a type of puzzle that originates from China. Tangram consists of a total of seven geometric objects: two small triangles, one medium size triangle, two large triangles, a square and a parallelogram. Studies designed using Tangram provide students with the opportunity to discuss the properties of geometric shapes such as size and similarity (Hacıömeroğlu & Apaydın, 2009). The achievement "Solves field-related problems" in the MEB (2018) achievements can be given as an example of an achievement that tangrams can use.

Algebra Tiles

It is a concrete model that is mostly used to represent unknown, variables and numbers and to express operations in teaching algebraic expressions and equations (Erdem & Doğan & Gürbüz & Şahin, 2017). In the MEB (2018) achievements, "Multilates algebraic expressions" and "Multiplies a natural number and an algebraic expression" objectives can be given as examples of achievements where algebra tiles can be used.

Fraction Cards

It is a concrete model that is mostly used to increase the understanding of the connection between part and whole regarding fractions and rational numbers and to show operation definitions on these subjects. Fraction cards can be stick-shaped, circle-shaped and transparent (Erdem & Doğan & Gürbüz & Şahin, 2017). In the MEB (2018) achievements, the achievement "Multiplies two fractions and makes sense of them" can be given as an example of an outcome in which fraction cards can be used.

Counting Stamps

It is a model preferred to represent negative and positive numbers, which is mostly used in integers, and to visualize operations with integers (Erdem

& Doğan & Gürbüz & Şahin, 2017). Among the MEB (2018) achievements, "Does addition and subtraction operations with integers and solves related problems" can be given as an example of an outcome where counting stamps can be used.

Counting Blocks

It is a model that is mostly preferred to indicate place values and operation definitions of natural and decimal numbers (Erdem & Doğan & Gürbüz & Şahin, 2017).

Geometry Sticks

It is a model that is mostly used to visualize side-angle relationships in teaching geometry subjects (Erdem & Doğan & Gürbüz & Şahin, 2017). In the MEB (2018) achievements, "Examines the properties of a vesicle by determining the congruent, reverse, inner reverse and external opposite angles formed by two parallel lines; determines whether the angles formed are congruent or supplementary; The outcome 'solves related problems' can be given as an example of an outcome in which geometry sticks can be used.

Result

This study focuses on concrete materials used in mathematics education, discussing the benefits they provide to students and some types of materials that can be used. When the data obtained from the study is analyzed, it is seen that concrete materials make learning more permanent by appealing to more sense organs of the students. In many studies in the literature, it has been stated that the use of concrete materials provides effective results in teaching most subjects of mathematics (Demir & Gün, 2023).

In this context, the use of concrete materials in learning environments saves the student from a passive state, provides large-scale learning opportunities, makes mathematics teaching more dynamic, allows mathematics to be discussed and increases student motivation (Kutluca & Akın, 2013). In addition, Bozkurt and Akalın (2010) stated that the use of concrete materials is a very useful teaching technique for students in transferring the concepts in the curriculum and ensuring more permanent learning (Demir, 2019).

In the light of the information obtained as a result of scanning the existing literature, although the mostly positive results of the use of concrete materials have been mentioned, there are also educators who do not agree with this, and it can be said that most of the educators who do not participate consist of the high school mathematics teacher group (Yazlık, 2018).

As a result, using concrete materials in mathematics education may be important in better conveying abstract concepts, especially for the primary school group. We can say that concrete materials are quite comprehensive. In

this context, it may be more useful to develop different concrete materials for the subject of the course and the relevant outcome or to be able to access and use the materials indirectly. Although the positive aspects of concrete materials are mostly mentioned in this study, care should be taken to use them carefully in lessons, to take into account the benefit of the students, and most importantly, not to dull the students' abstract thinking skills. Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

Suggestions

Some suggestions can be made based on the results of this study and the findings of the sources examined in this study.

- Although many materials used in mathematics education may have low costs, seasonal financial support can be provided to schools since the situation of teachers, students and schools may vary.
- Programs can be organized for teachers to help them decide on which subjects concrete materials should be used in mathematics education and to have information on how to make and access these concrete materials. Extensive preparation can be made before teachers use the material.
- Both the production phase and the application phase of concrete materials can be a painful process that may require a lot of time. Therefore, considering the current curriculum, this painful process can be greatly alleviated by increasing the number of mathematics courses or increasing the duration of applied mathematics courses.
- The structure and characteristics of the material used can be selected in accordance with the subject to be explained, the achievement and the grade level of the student. Many examples of the structures and features mentioned here can be given, such as the color, size, shape, and font of the material.

The suggestions given above may help to overcome the difficulties and problems that may be encountered from the production process of concrete materials used in mathematics education to the application process. Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). In addition, these suggestions may also show how easy it is to use concrete materials when the necessary conditions are met.

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ON THE CONTRIBUTION OF GEOGEBRA SOFTWARE TO TEACHING MATHEMATICS

Beyza Sertkaya[1], İbrahim Enam İnan[2]

Abstract

In this study, Geogebra software was mentioned and the effect of this software on mathematics education was examined. In the research, the literature on Geogebra was scanned and important expressions were determined. A descriptive analysis of the data obtained was made. It is very important for today's mathematics teachers to be trained as individuals who can use technology most effectively in educational environments as well as their field knowledge. Therefore, a teacher who follows innovations and aims to equip himself with the qualifications required by the digital age should have information about the use of Geogebra, a dynamic mathematics software, and its possible effects on the student. According to research, the inclusion of Geogebra in educational environments has produced positive results for both teachers and students. Studies indicate that dynamic learning environments will benefit students in gaining high-level learning skills.

Key Words: Mathematics, Mathematics Education, Geogebra Software, Dynamic Mathematics Software

Introduction

"Mathematics is a woman; logic is her clothes." (Kay Mcklein, 2002) For this logic, the following idea comes to mind: Mathematics; It is a systematic and organized theory (Nasibov & Kaçar, 2005). For mathematics education, it is the process of providing the person with the mathematical knowledge and skills required in daily life, teaching problem solving and gaining the problem-solving approach in daily life (Çekici & Yıldırım, 2011). Teachers have a great role in students' success and understanding of the lesson in mathematics education. Teachers' attitudes towards mathematics and teaching the lesson have an impact on students. The teacher must have competence in his field and be able to follow the developments in his field (Karakaş Türker and Turanlı, 2008). In addition, he should expand his knowledge by doing research, if necessary, to answer questions from students (Erden, 1998). For this reason, mathematics teachers may generally have a certain degree of mathematics anxiety, including during their undergraduate education and professional lives.

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In a study, prospective teachers associated the reasons for their mathematics anxiety with the effectiveness of mathematics teaching practices and their beliefs about mathematics teaching (Zengin, 2017). The negative conditions created by mathematics anxiety in the learning and teaching process can be eliminated by effective mathematics teaching (Tobias, 1998). As a matter of fact, Gresham (2007) found that pre-service teachers' mathematics anxiety decreased when concrete manipulatives were used in the learning environment. In addition to concretization, supporting the mathematics learning environment with visuals also reduces mathematics anxiety (Şengül & Dereli, 2010). In this process, it has been found that environments supported by technology also help reduce mathematics anxiety and increase interest in the mathematics learning environment (Sun & Pydrowski, 2009; Waxman & Huang, 1996).

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2020). Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

Being among the developed countries in the world will only be possible by being equipped with the needs of the age. Developments in the field of technology in the last century have increased countries' orientation towards technology and they have focused more on science and mathematics education in their educational policies (Özçakır, 2019). The movements observed in science and mathematics education research in the world manifested themselves in Turkey in the 2000s. In 2010, the Movement to Increase Opportunities and Improve Technology (FATİH) was put into practice by the Ministry of National Education. With this comprehensive project, schools were provided

with important technological equipment (MEB, 2012). One of the eight key competence types specified by the Ministry of Education is digital competence. These competencies are determined by the Turkish Competencies Framework (TQF). Digital competence; It covers the safe and critical use of information and communication technologies for work, daily life and communication. This competence is supported through basic skills such as accessing information and using computers to evaluate, store, produce, present and exchange information, as well as participating in common networks and communicating through the Internet (MEB, 2024).

First of all, by assuming the role of the teacher in the course processes in teaching the subjects and concepts related to the course, information technology tools, which aim to teach students the relevant subjects and achievements in extracurricular environments, have an instructive role. Interactive lecture videos on EBA and lecture videos on YouTube can be given as examples of this. Information technologies have a tool role in helping students research concepts related to the subject and clarifying relevant problem situations, in facilitating routine tasks such as calculations, drawings and analysis, that is, in using information technologies as learning materials. Software and devices such as calculators, graphing calculators, dynamic geometry software, computer algebra systems are among the information technologies used as tools. Information technology tools that have a learner role are programming tools that mostly deal with algorithmic operations. Tools in which programming languages are written and tools in which visual programming is carried out, such as Scratch, are used in accordance with this role. In particular, some dynamic geometry software and computer algebra systems that have a mathematical command interface in the background, such as Geogebra, can also be used in accordance with this role (Tatar &Tatar, 2008).

There are two basic software used in mathematics lessons. These are BCS (Computer algebra system) and DGY (dynamic geometry software). BCS is a software that aims to obtain precise results by performing operations with numbers, symbols and algebraic expressions. DGY, on the other hand, is a software that aims to move the structure, drag the shapes, measure and visually present the relationships between geometric structures. GeoGebra software was designed in 2002 to offer both BCS and DGY features together. GeoGebra software first emerged in 2002 as part of the master's thesis prepared by Markus Hohenwarter at the University of Salzburg. Markus Hohenwarter continued his studies at Florida Atlantic University after 2006. Here, within the scope of a project in the field of teacher education, he worked to ensure more effective use of GeoGebra in mathematics learning environments. On the other hand, GeoGebra Forum and GeoGebrawiki internet environments were created in 2005, and the international GeoGebra institute was established in 2007

(Şimşek & Yaşar, 2019). The software has been translated into approximately 70 languages. 140 national GeoGebra institutes have been established in different countries. GeoGebra applications are included in the textbooks of many countries (Hohenwarter & Lavicza, 2007; Lavicza, 2011). One of the reasons why Geogebra is so preferred is that it is free to use. While Geogebra can be used free of charge over the internet, it can also be downloaded free of charge to tablets, computers and smartphones and applied without using the internet. Studies on GeoGebra in Turkey started in 2005. GeoGebra was introduced to educators and researchers at an international congress held in Turkey in 2006. In 2009, GeoGebra's user manual was translated into Turkish (Doğan, 2013). Ensuring that mathematics teachers can use dynamic software as an effective teaching tool is thought to be one of the teacher training problems in our country. For this purpose, within the scope of the Eurasian GeoGebra Meeting (AGT) within the scope of the 3rd Learning for the Future Conference, a workshop on "Using GeoGebra in mathematics education" was organized for nearly 100 teachers from different cities of Turkey for a total of 6 hours over 2 days. In this workshop, teachers had the opportunity to listen to information about Geogebra from Turkish and English sources. Basic software usage, basic computer literacy and technology integration skills can be listed among the factors that mathematics teachers who want to create more effective learning environments for their students by integrating technology into their classrooms should consider for their professional development. In summary, it is very important for today's mathematics teachers to be trained as individuals who can use technology most effectively in education and training environments, in addition to their field knowledge. For this purpose, they should have knowledge about the use of GeoGebra, a dynamic mathematics software, and its integration into educational environments (Kabaca, et al., 2010).

Studies on multiple representations emphasize that the connections between representations are strengthened through transitions between representations, especially since technological environments allow rapid and effective access to many representations at the same time (Akkoç, 2006). GeoGebra; It enables rapid transitions between representations by transferring mathematical symbols, graphics and these values to the table in a dynamic process with algebra, drawing board and spreadsheet view windows, and with this feature it differs from other dynamic geometry software and computer algebra systems (Aktürkmen et al., 2010).

Purpose of the Research

The purpose of this study is to evaluate the effect of Geogebra use in mathematics lessons. By using information technology tools in learning and teaching environments, the subjects and concepts in the mathematics curriculum can be concretized and these concepts can be supported with interactive multiple

representations. In this research, Geogebra, one of the dynamic geometry software of information technology tools, was examined. Mathematical objects can be easily created in Geogebra, with its structure that can be commanded entirely according to mathematical expressions. It is assumed that Geogebra software, which has a simple interface, can be used easily by students and teachers. Geogebra, a dynamic computer software that draws graphics, provides the opportunity to access multiple representations of linear equations quickly and effectively. It is aimed that such technological opportunities will contribute to the correct establishment of concepts in students' minds, as Geogebra displays many algebraic expressions and graphic examples at the same time and allows students to experiment and reach conclusions.

Research Method

In this study, the impact of Geogebra software on students and its contributions to social and economic development were examined. The research uses a literature review method to analyze existing academic literature in depth. In this process, both printed and digital resources were scanned and important information, theories and results about Geogebra were determined.

Study Group

The working group of the research created articles and theses written on Geogebra, obtained from the sources of the Council of Higher Education Thesis Center (YÖK THESIS) and the National Academic Network and Information Center (ULAKBİM). These studies were selected according to the determined criteria

Data Collection Tool

In the research, literature on Geogebra was collected from YÖK TEZ and ULAKBİM databases by a systematic scanning method. This process was carried out carefully in accordance with the purpose of the research.

Analysis of Data

The collected data was analyzed using the descriptive analysis method. This approach allowed the data to be rearranged in accordance with the research questions and evaluated from different perspectives (Şimşek & Yıldırım, 2003).

Dynamic Geometry Software and Geogebra

Dynamic Geometry Software

Dynamic geometry software is software that enables the visualization of geometric objects based on the Euclidean axioms that we generally deal with in school mathematics. With their dynamic software, they enable students to perform dynamic manipulations by allowing them to interact with the created geometric objects and move points and objects. "Geometric Supposer", known as the first dynamic geometry software, was developed by Schwartz and

Yerushalmy (1985) for Apple computers. With this dynamic geometry software, the construction of geometric shapes, generalizations and measurements could be made with commands given from the keyboard. After the Geometric Supposer software, Logo Geometry and the currently widely used Geogebra, Cabri, Geometer's Sketchpad and Geometry Expressions software were developed.

Dynamic geometry software is tools that enable mathematicians to test theorems, investigate problem situations, create new situations and examine mathematical objects dynamically and interactively. Thanks to these tools, it becomes possible to conduct experiments in geometry by changing the variables both visually and symbolically, interacting with geometric objects and observing the results of the changes (Forsythe, Hill & Hannafin, 2001). Within the scope of school mathematics, it becomes possible for students to make observations on geometric objects, manipulate objects, record the results and obtain information about geometric concepts in an experimental environment. Well-defined shapes created in dynamic geometry software always preserve their basic properties even as a result of various changes.

Although Geogebra software also allows drawings like Geometer's SketchPad, since it has analytical geometry-based programming, it also allows the creation of any geometric object with its equations and representations in the analytical plane. In Geogebra, you can create a geometric object with basic drawings using Euclidean drawings by adhering to the geometric shape definition, or you can create it by simply defining the object geometrically on the keyboard. For example, you can draw a triangle using the line and angle tools, or you can create an equilateral triangle by writing its equation. For this reason, Geogebra provides visualization of objects that appeal to more areas of mathematics learning than Geometer's SketchPad. Although Geogebra is considered as a dynamic geometry software, it would be more accurate to define Geogebra as a dynamic mathematics software because it is possible to create mathematical objects for all learning areas in the mathematics curriculum with Geogebra. It is possible to design learning activities with Geogebra for most of the concepts in school mathematics.

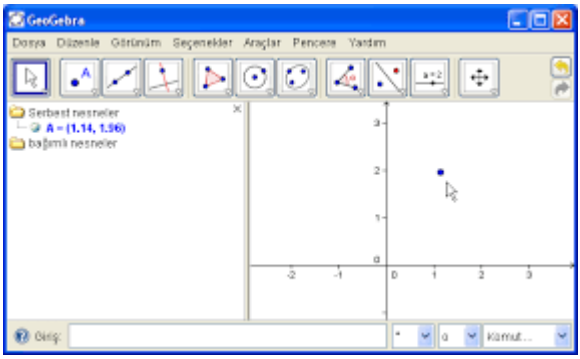
Installing Geogebra

GeoGebra is a program developed in Java environment. GeoGebra's official website is opened using the link http://www.geogebra.org.

Geogebra's User Interface

When the GeoGebra program is opened, there is a Title Bar at the top of the window, a Menu Bar below it, and a Tool Bar below the menu bar.

The left side of the area under the toolbar is the algebra window, the area in the middle is the graphics window, and the area in the middle is the spreadsheet on the right of the screen using the Ctrl + Shift + S key combination. The part below the window is called the Login Area. Using the input field; The commands of the mathematical object to be created are entered and thus the desired mathematical object is created. Objects can be created in three different ways using the toolbar, input field, and spreadsheet.



There are free objects and dependent objects in the algebra window.

The points created (points A, B) are called free objects (independent objects), as seen in the algebra window. A line created using two of the points is called dependent objects in the algebra window because its coordinates depend on points A and B.

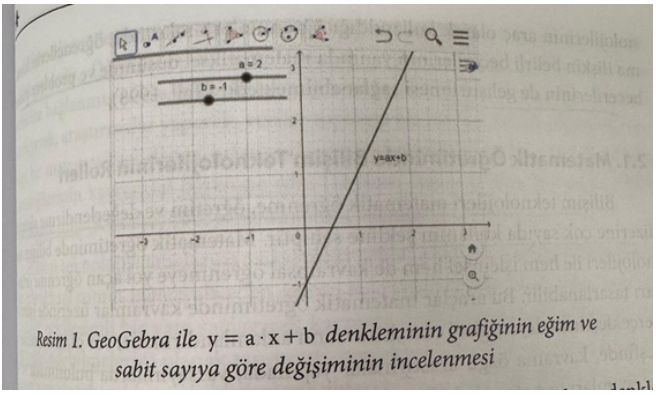
The graphics window is also called the drawing board. The properties mentioned here are similar for all mathematical objects except the point. For the sake of example, the explanation was made by focusing on the point object.

The spreadsheet is also included in the GeoGebra program as a Spreadsheet. The spreadsheet can also be accessed by CTRL+SHIFT+S or by selecting Spreadsheet from the View menu. In Removing the Spreadsheet, the spreadsheet is removed when CTRL+SHIFT+S or selecting Spreadsheet View from the View menu. The spreadsheet is organized in a structure similar to Microsoft Excel.

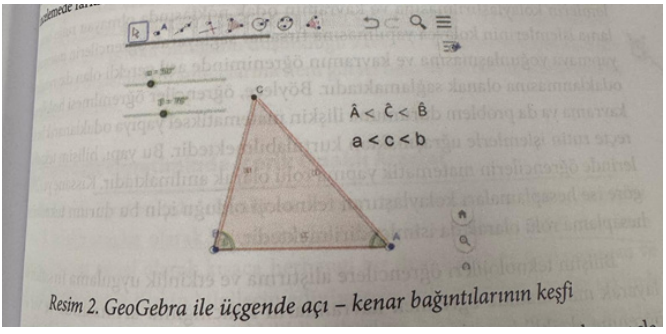
It is important to stick to the actual usage of mathematical expressions when giving commands to Geogebra. For example, when defining a point, the naming is done with capital letters and the location of the point is given in parentheses. While the command given as A= (1,2) defines point A as it should, the command given as a= (1,2) defines a vector. For this reason, it is very important to use the correct expression when creating mathematical objects in Geogebra.

Geogebra Examples in Mathematics Education

For example; In Geogebra, a dynamic geometry software, the student can instantly see what shape the graph will take by changing the slope and constant in the 5x-1=y equation. With these tools, students can have the opportunity to observe the angle-side relationship in the triangle more concretely interactively. Thanks to opportunities like these, students can progress on the path to knowledge by seizing different opportunities to examine given problem situations through the effective use of digital learning tools.



Resim 1. GeoGebra ile $y = a \cdot x + b$ *denkleminin grafiğinin eğim ve sabit sayıya göre değişiminin incelenmesi*



Resim 2. GeoGebra ile üçgende açı – kenar bağıntılarının keşfi

The instant feedback feature of technological software is one of the most important features that distinguish them from traditional concrete materials. In this way, by creating interactive multiple representations of the concepts

in mathematics teaching, students can be enabled to associate concepts with symbolic representations. With this structure, students can associate information and work actively in the learning activity by analyzing changes in concepts, creating assumptions and verifying these assumptions (Tutkun, Güzel, Köroğlu & İlhan, 2012). In this way, students can develop their mathematical thinking and association skills, as well as certain conceptual skills (Tall, 1998).

Result

In this study, focusing on Geogebra software, the features of Geogebra, its place and importance in mathematics education are mentioned. Findings show that using dynamic software in mathematics education contributes to students' development of high-level skills such as meaning, association and reasoning (Hazzan et al., 1997). Research has shown that geometry software with dynamic features gives students the opportunity to abstract much more than commonly used traditional studies (Güven & Karataş, 2003).

As a result, it will be necessary for us to use this software for the acquisition of digital literacy competence, one of today's competences, and for constructive mathematics education. In this way, students can gain different perspectives on their studies on mathematics and geometry.

Suggestions

Teachers must have the necessary technological competencies to overcome the difficulties in mathematics education. For this reason, digital materials should be supported in teacher training curricula and studies should be included to inform teacher candidates on this subject. The curriculum should be rearranged to increase the technological competencies of teacher candidates. In schools, the possibilities of technology should be used to provide environments where students can make connections with daily life. Interactive mathematics teaching environments should be created in schools. Necessary technological investments to ensure student participation should be supported. Seminars should be given to teachers to use dynamic mathematics software. Teachers should be motivated to use dynamic digital software in classroom environments, and teachers' awareness should be raised through necessary in-service training. Authorities should support more studies that will support and popularize the use of technological tools in the classroom environment. Academic studies on this subject should be supported and scholarships and funds should be provided for their dissemination. The use of technology should be supported in measurement and evaluation studies, and the convenience of technology should be used in evaluating students. In this case, rater-related evaluation errors will be prevented and teachers will be facilitated in the evaluation phase of students.

Not only Geogebra but also other dynamic software should be examined in detail. Studies in undergraduate and graduate programs should be increased.

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7. SINIF ÖĞRENCİLERİNİN ZİHİNDEN İŞLEM YAPMA BECERİLERİNİN GELİŞMESİ

Zeynep Salman[1], İbrahim Enam İnan[2]

Abstract

Mental processing is the process of mentally finding the correct answer to any mathematical question without using any calculation tools (Reys, 1984). Instead of using known rules, students can develop strategies specific to their own thoughts by making mental calculations and reach results in a faster and more practical way (Beberman, 1959). In this study, 7th grade students were examined to improve their mental processing skills. For this study, two different 7th grade students (60 in total) studying in a secondary school were selected. One of the classes was assigned as the experimental group and the other as the control group. It was observed how 7th grade students, an important stage of secondary school, quickly solved the problem they encountered. Students' unique perspectives were taken into account and noted. It is important that the person who acquires mental calculation skills also has procedural fluency. Procedural fluency is one of the skills that should be used frequently in doing and teaching mathematics. After the study, it was seen that the students' perspectives on the problem were generally similar. By providing students with appropriate activities in and outside the classroom, it can contribute to the positive development of their number sense and the development of their ability to perform mental operations.

Key Words: Mental Operation, Mental Calculation Skill, Procedural Fluency

Introduction

Today, changing and developing technology greatly affects people's mental structure. We must adapt to developing conditions and educate our students in line with this information. The most important thing that enables mental skills to emerge is the individual's thinking. When a person thinks and questions, he improves his mental processing skills. Having decision-making and problem-solving skills shows that a person thinks and questions. A student who thinks and questions destroys his/her prejudices against mathematics, which is one of the important factors that increase mathematics success. While teaching mathematics, we want the information we convey to the student to

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be assimilated by the student. The student must make sense of the information he has absorbed in his own inner world. The student can solve the problem he encounters in mathematics class in a shorter time by performing mental operations. This condition, also called procedural fluency, makes mathematics more understandable and interesting. Mental calculation promotes a better understanding of the structure and basic properties of numbers (Reys, 1984). With the help of mental calculation, the person acquires a unique skill. A student who has problem-solving skills develops different perspectives on the problem. The student who has the ability to perform mental operations is the type of student who thinks and produces ideas. As teachers, we must help our students reveal this skill.

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2020). Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

Purpose of the Research

The purpose of this study is to explain students' ability to mentally perform mathematical operations quickly and accurately. Students who can calculate mentally develop their own ways and answer the question quickly. Mental processing is one of the important skills that should be used today. The research is about how the 7th grade secondary school student group solved the problems in the mathematics course by developing mental skills and different perspectives. An answer is sought to the question of how quickly and in different ways the student can solve the problem. It is important to develop this skill so that they can gain more speed in the face of new generation questions.

Research Method

A pretest-posttest, control group design was used in the research. The pretest-posttest control group design is a commonly used mixed design. Participants are measured regarding the dependent variable before and after the experimental procedure. However, this pattern is unrelated due to the comparison of measurements of experimental and control groups consisting of different subjects (Büyüköztürk, 2007).

Study Group

The study group of this research consists of a total of 60 seventh grade students (24 girls, 36 boys) studying in two different branches of a secondary school in Ankara. The sample of the research was determined by simple random sampling. One of these branches was assigned as the experimental group and the other as the control group.

Transaction Process

A total of 60 seventh grade students studying in two different branches of a secondary school were selected for this study. One of these branches was assigned as the experimental group and the other as the control group. Before the application started, a pre-test was applied to the experimental and control groups. At the end of the application, a post-test was administered to the experimental and control groups. Additionally, a semi-structured interview form was applied to the experimental group.

Data Collection Tool

In this study, a semi-structured interview form developed by the researcher was used as a data collection tool to determine the mental calculation methods used by 7th grade students when faced with any mathematical problem. This interview form is a type of interview used to collect the same type of information from those interviewed about a subject in order to examine it. In addition, the questions in the Ministry of Education books were applied as pre-test and post-test data collection tools.

Analysis of Data

As a result of the research, the data obtained from the interview form was analyzed using descriptive analysis. According to Yıldırım Şimşek (2011), descriptive analysis is an analysis approach that includes the steps of processing qualitative data, defining the findings, and interpreting the identified findings based on a predetermined framework. In addition, the data obtained from the pre-test and post-test were analyzed using the SPSS 21 package program.

Development of Data Collection Tool

In this study, a semi-structured interview form was created by the researcher to be administered to students. The researcher prepared the questions of the

interview form by interviewing mathematics teachers who are experts in their field. Then, the prepared interview form was shown to three academicians who are experts in the field and was given its final form thanks to the feedback received.

Result

The semi-structured interview form administered to 7th grade students enabled a detailed exploration of the students' perspectives, experiences and perceptions in the class. Students' comments about how they could solve the new generation 7th grade mathematics problems involving addition and subtraction without using formulas or operations directly were examined. As a result of this analysis, it was seen that some students visualized the question with different objects in their minds, some reached their conclusions by guessing, and some reached their conclusions directly by adding the given numbers in their minds. Common answers are categorized. After the meeting with the students, their opinions were taken and they were asked how the solution to the problem could be different. Each student's unique comments were taken into account and recorded. After the study, it was seen that the students' perspectives on the problem were generally similar.

Suggestions

By providing students with appropriate activities in and outside the classroom, it can contribute to the positive development of their number sense and the development of their ability to perform mental operations.

It is thought that if students are provided with appropriate learning environments, they will be able to use mental processing strategies and develop new mental processing strategies. Because applying different mental calculation methods provides originality. It causes an increase in the mathematical success of the student who acts and implements his own ideas. The ability to mentally calculate increases students' desire and self-confidence towards mathematics (Rubenstein, 2001), and the ability to mentally calculate is and should be one of the most valuable skills that children in the developmental age can have (Patilla, 2002; cited in Cheshire et al., 1999; Keçeci and Akademi, 2011).

It is recommended that teachers use plenty of activities that can be mentally processed in their lessons and direct students to do mental operations. We should ask more questions that require mental calculation in which the student actively participates. We must make the student think and keep his interest in mathematics alive.

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ON MISCONCEPTIONS IN MATHEMATICS EDUCATION

Şevval Olur[1]

Abstract

For many people, learning and applying mathematics can be difficult. The word mathematics covers a wide range of ideas and activities (Cooke, 2007). It can be said that mathematics is based on a logical order and operations. Finding, discovering, and then making sense of this order or regularity literally means doing mathematics (Van de Walle, Karp, & Williams, 2014). Mathematics cannot be considered independently of numbers. It involves solving problems related to the concepts of shape and space, time, weight and mass, capacity and money, as well as understanding numerical data (Edwards, 2007). In order to learn mathematics, mathematical concepts must first be learned well. As in all disciplines, teaching mathematics in accordance with its structure is directly related to students' understanding of mathematical concepts (Baykul, 2003). Teaching concepts has an important place in the curriculum and different outcomes are included for these concepts from the pre-school period to the last stage of primary school (Erdoğan and Erdoğan, 2009). The study is a research on the reasons and solution suggestions for misconceptions in mathematics education.

Key Words: Concept, Misconception, Mathematics Teaching.

Introduction

One of the main purposes of education is; To raise individuals with high-level skills such as reasoning, critical thinking, association and problem solving (TTKB, 2013a). Courses in primary education programs can be very important in developing these skills. However, among these courses, mathematics has a special importance in developing reasoning, critical thinking and association skills as it is directly related to problem solving (Baki, 2008). Therefore, effective education should be given to improve mathematical skills, especially from the primary school level.

An education appropriate to the structure of mathematics should be aimed at the following three purposes;

1) To help students understand mathematical concepts,

2) To help them understand mathematical operations,

3) To help them establish connections between concepts and operations (Baykul, 2002).

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Observing these goals may be of great importance for the internalization of mathematical concepts. As stated by Ülgen (2004), individuals who have a good command of concepts can develop principles by making sense of the world correctly.

A misconception is defined as a person's interpretation of any subject in a different way than an expert in the field (Baki, 2006). Stating that misconceptions contradict scientific realities and thoughts, Çıldır and Şen (2006) emphasized that misconceptions have a hindering effect on meaningful learning. In order to prevent misconceptions, it may be important to detect possible misconceptions in advance. Because misconceptions may not only result from student failure, but may also be the result of the teaching model followed. Wrong models and methods can both cause misconceptions and increase existing misconceptions. For these reasons, it is important for teachers to adopt approaches to prevent misconceptions before they arise, by choosing appropriate teaching methods, especially in subjects where misconceptions are more expected (Zembat, 2010).

Purpose of the Research

The aim of this study is to learn the reasons for misconceptions in mathematics teaching and to offer solutions. By examining the existing literature from a broad perspective, the research aims to show to what extent the models and methods used in mathematics teaching prevent misconceptions that may occur.

Research Method

In this research, the literature review method was used. The digital resources and written books were examined in depth and various data on the subject were obtained.

Study Group

The study group of the research consisted of articles and theses written on misconceptions in primary school mathematics education obtained from digital sources.

Data Collection Tool

In the study, a systematic review was conducted on the resources written on misconceptions in primary school mathematics education and data was collected by this method. Systematic screening is the process of objectively scanning original studies published on a particular subject and synthesizing the found studies in order to find an answer to a research question on a particular subject. This process was carried out meticulously in accordance with the purpose of the research.

Analysis of Data

The data obtained was examined with the descriptive analysis method. Descriptive analysis method is the in-depth analysis of many independent

qualitative or quantitative studies on a specific subject. The data obtained in this process was analyzed in depth from different perspectives.

Result

Primary education is a stage where students are taught the necessary knowledge, skills, terms and concepts to be aware of mathematical concepts and use them effectively (Duran, 2013). For this reason, a misconception acquired in primary education can directly affect the information learned both in secondary education and in later education; Depending on the situation, it may make the acquisition of new information difficult or cause misunderstanding of new information.

Whether education is good or bad in a country can take the country forward or backward in every sense (Tutak, İç, Gün, Emül, 2009). Technology reveals individual success opportunities that were previously considered impossible in today's educational fields (Tutak, İlhan, İç, Kılıçarslan, 2018; Bork, 1987). Thanks to mathematics, teacher candidates gain knowledge about different teaching principles and methods and have the opportunity to transform their experiences into practices (İlhan, Tutak, İç, Ekinci, 2020). Various tools are used in mathematics education to develop mathematical skills (Nayıroğlu, Tutak, 2024). It has been observed that it increases students' motivation, concepts are learned concretely, students are more active in lessons, lessons are more permanent, and students are more resistant to mathematics lessons (Nayıroğlu, Tutak, 2023). It was also stated that students increased the time they spent focusing on the lesson, the concepts were learned concretely, students were more active in the lessons, the lessons were more permanent, and it positively affected the students' attitudes towards the mathematics lesson (Tutak, Nayıroğlu, Süzen, 2023). As the importance of mathematics shows an increasing trend all over the world, some students, whose number is considerable, may experience some problems during mathematics education (Baldemir, İç, Tutak, 2020). Mathematics is known as one of the most important tools that improve thinking (İç, Tutak, 2018; Umay, 2003).

At the same time, studies reveal that teachers and teacher candidates have deficiencies in terms of pedagogical content knowledge and awareness of student misconceptions (Asquith, Stephens, Knuth and Alibali, 2007; Tanışlı and Köse, 2013; Gökkurt, Şahin, Soylu and Doğan, 2015; Gürbüz and Alibali, 2007). Erdem, 2015; Karaağaç and Köse, 2015; Bayraktar and Yılmaz, 2017). This deficiency may negatively affect misconception detection before knowledge transfer. This can turn overlapping misconceptions into a knot that becomes increasingly difficult to unravel.

Suggestions

Constructing the information to be learned by the learner himself can largely prevent misconceptions. At the same time, correcting a situation where there is a misconception with one's own effort can provide more permanent learning. For this, learning journals can be very useful. Learning journals, which encourage learners to write down their own experiences, questions, and thoughts, include ideas and concepts (Hindman, Stronge, & Tucker, 2004). Harmin and Toth (2006) defined learning diaries as "writings in which students write their opinions about their learning experiences and which the teacher checks periodically."

Students can structure the newly learned knowledge on top of their previous knowledge. Even though students correctly observe certain common features of the examples, they may get stuck on an example that causes misconceptions and thus learn an incorrect procedure (Ashlock, 2006). Therefore, identifying and eliminating misconceptions in preliminary information may be of great importance.

In the light of the studies conducted, it may be of great importance to give more importance to the detection and elimination of misconceptions in the postgraduate education of teacher candidates. At the same time, teachers' self-improvement in terms of the training to be given and regular in-service training can be among the solutions deemed necessary to prevent possible misconceptions.

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