SCIENCE TO THINK, MATH TO DESIGN, SPORTS TO LIVE II

EDİTOR: DR. MEHMET POLAT

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CONTENTS

ANALYSIS OF THE SCIENCE QUESTIONS IN THE HIGH SCHOOL ENTRANCE SYSTEM ACCORDING TO THE REVISED BLOOM'S TAXONOMY

Erdal CANPOLAT[1], Kübra AYYILDIZ[2], Eda CANPOLAT[3]

Abstract

In this study, science questions in secondary school entrance exams were examined in accordance with the cognitive levels of the Revised Bloom's Taxonomy. The research involved document analysis of science questions from the "Central Exam for Secondary Education Institutions Admitting Students through Examination Numerical Section A Booklet" between 2018 and 2025. According to the results, 31.88% of the science questions were at the analysis level, 31.25% at understanding, 28.13% at application, 6.88% at evaluation, and 1.88% at remembering. The findings indicate that the questions were not prepared in a balanced manner in accordance with the steps of the Revised Bloom's Taxonomy, with notable deficiencies particularly in the evaluation, remembering, and creating levels. When we consider the changes made to the science curriculum by the Ministry of National Education in 2018, which aimed to emphasize higher order cognitive skills, it is evident that the questions are inconsistent with the curriculum goals. Minimizing the deficiencies found in centralized exams, especially in assessing high-level cognitive skills, would contribute positively to students' advanced cognitive development. It is recommended that while determining objectives in the question preparation phase, the appropriate taxonomy levels should be integrated and carefully aligned with the characteristics of the Revised Bloom's Taxonomy.

Keywords: Revised Bloom's Taxonomy, Science Education, High School Entrance Exam

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Introduction

Keeping pace with an ever changing world requires not only understanding science but also applying it effectively. From this perspective, the quality of science education has become a significant indicator of a country's level of development. For a student who is at the center of education to comprehend and interpret the modern world, they must acquire high level cognitive abilities and learn how to access knowledge and through which cognitive stages.

The learning process encompasses exploration, inquiry, argumentation, and product design. The science curriculum plays a crucial role in facilitating the transfer of scientific knowledge to practice, concretizing abstract concepts, and nurturing creative thinking skills through learning environments that support the development of such skills (MEB, 2018). Accordingly, with the updated science curriculum introduced by the Ministry of National Education in 2018, the aim was to raise individuals who can reach knowledge not through rote memorization, but by critically analyzing and evaluating situations.

Just as the quality of instruction is important, so is the effectiveness and purposefulness of the feedback process. To achieve desired behavioral changes and concretize targeted learning outcomes, an assessment process is necessary. Assessment refers to the process of making judgments by comparing observed outcomes against certain standards or criteria (Turgut & Baykul, 2021). In this context, an objective measurement and evaluation system is essential for assessing students' knowledge levels and skills (Şad & Şahiner, 2016). It is particularly important to determine to what extent the learning outcomes targeted in the science curriculum are achieved.

In Türkiye, exams are administered to assess students' academic success and place them in appropriate high schools based on the knowledge accumulated over eight years of basic education. While the number of students taking the exam increases annually, the number of qualified schools remains limited. Therefore, the measurement and evaluation system used to match students with schools according to their success and talents plays a critical role. Since 1999, 8th grade students in Türkiye have been transitioning to upper secondary education through centralized examinations. These exams have undergone frequent name and structure changes over the years: from 1999 to 2004, the High School Entrance System; from 2004 to 2008, the Secondary Education Institutions Exam; from 2009 to 2013, the Level Determination Exam; from 2013 to 2018, the Transition from Primary to Secondary Education Exam; and since 2018, once again, the High School Entrance System (MEB, 2018).

High quality science education begins with well-constructed questions (Marbach & Sokolove, 2000). While lower-order questions are useful for assessing factual knowledge, they do not contribute to the development of diverse thinking skills. In contrast, higher order questions are beneficial in helping students access knowledge, refine their own learning styles, and evaluate what they know. It is expected that the questions posed to students should not be based on memorization, but should encourage critical and creative thinking, reasoning, and the generation of new information. Ideally, the questions should reveal not only what students know, but also what they misunderstand and why (Dindar & Demir, 2006). In science education, alongside lower order skills, questions that assess analytical thinking, interpretation, and evaluation i.e., higher order cognitive skills should also be included (Demiröz & Ertem, 2022). These high-level cognitive skills, which the science curriculum aims to foster, enable individuals to objectively evaluate their environment and reach conclusions.

To ensure that instructional objectives are clearly defined and consistently understood and to facilitate observable behavioral change in students various educational taxonomies have been examined, with Bloom's taxonomy being selected as the most appropriate (Çiftçi & Aydın, 2023). Bloom's taxonomy consists of six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation each representing a different level of cognitive complexity. As perspectives on knowledge evolved, revisions were made to Bloom's taxonomy. After six years of development, the **Revised Bloom's Taxonomy** was introduced. It includes two main dimensions: the **knowledge dimension** (factual, conceptual, procedural, and metacognitive knowledge) and the **cognitive process dimension**, which consists of six levels:

1. ***Remembering:*** Retrieving information from long-term memory. This includes two sub-skills: recognition and recall.
2. ***Understanding:*** Deriving meaning from verbal, written, or graphic messages. Includes interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
3. ***Applying:*** Using a procedure in a given situation. Involves executing and implementing.
4. ***Analyzing:*** Breaking material into parts and determining how those parts relate to one another and to the overall structure. Includes differentiating, organizing, and attributing.
5. ***Evaluating:*** Making judgments based on criteria and standards. Includes checking and critiquing.

6. ***Creating:*** Putting elements together to form a new, coherent, and functional whole. Involves generating, planning, and producing (Tutkun, Demirtaş, Arslan, & Gür Erdoğan, 2015).

In the literature, many studies examining question types in centralized placement exams have focused on Bloom's Taxonomy (Aslan, 2011; Ayvacı & Türkdoğan, 2010; Başol, Yıldız & Tutkun, 2021; Ekinci & Bal, 2019; Güleryüz & Erdoğan, 2018; Gündüz, 2009; Güven & Aydın, 2017; Üner, Akkuş & Kormalı, 2014). In light of these studies, the primary aim of this research is to determine which cognitive levels the science questions in the High School Entrance Exam introduced in 2018 and onward correspond to according to the Revised Bloom's Taxonomy. This study also expands the scope by including the 2023 exam. Additionally, it compares the consistency and cognitive distribution of questions from 2020 to 2023, a period when exams were limited to first-semester topics. The study also aims to contribute to the literature by analyzing the unit distributions of science questions. Specifically, it explores how the science questions in the High School Entrance Exam are distributed across the cognitive process levels of the Revised Bloom's Taxonomy.

Methodology

This study employed the qualitative research method of **document analysis,** which involves analyzing written materials such as books, articles, and official documents to gather data (Karasar, 2019). This method allows researchers to collect the necessary data without direct observation or interviews (Yıldırım & Şimşek, 2021).

Data Collection and Analysis

The data set includes science questions from the "Numerical Section A Booklet" of the Central Exam for Secondary Education Institutions from 2018 to 2025, totaling 160 questions. Each question was analyzed and classified according to the cognitive process dimension of the Revised Bloom's Taxonomy.

Result and Suggestions

Table 1 presents the unit-based distribution of science questions in the High School Entrance System.

Table 1. Distribution of Science Questions by Units in the High School Entrance Exam

	2018	2019	2020	2021	2022	2023	2024	2025
Human Reproduction, Growth, and Development	3	-	-	-	-	-	-	
Light and Sound	2	-	-	-	-	-	-	
Seismic Activity and Atmospheric Phenomena	1	-	-	-	-	-	-	
Seasons and Climate	-	1	3	2	1	3	2	1
DNA and Genetic Code	-	3	8	5	4	8	4	3
Pressure	-	2	5	2	2	5	2	2
Matter and Industry	6	5	4	5	5	4	5	5
Simple Machines	2	2	-	2	2	-	2	2
Energy Transformations and Environmental Science	3	4	-	4	4	-	3	4
Electric Charges and Electrical Energy	3	3	-	-	2	-	2	3

When analyzing the unit distribution of the High School Entrance System science questions administered between 2018 and 2025, it is evident that some units have become more dominant over time, while others have been entirely excluded from the exam scope in subsequent years. One of the most prominent findings is the consistent presence of the unit *"Matter and Industry"*, which appeared in every year of the exam with 4 to 6 questions, establishing itself as a fixed component of the curriculum. This consistency may be attributed to both the unit's broad content and its relevance to students' daily lives. On the other hand, the *"DNA and Genetic Code"* unit gained significant prominence between 2019 and 2023, appearing with up to 8 questions in some years. However, the number of questions from this unit dropped to 3-4 in 2024 and 2025. This shift may reflect an attempt to balance the curriculum load or changes in outcome-based assessment policies. The *"Energy Transformations and Environmental Science"* unit was omitted from the exam in certain years (e.g., 2020 and 2023), while in others, it was represented with 3-4 questions. These fluctuations could be influenced by evolving environmental awareness within education policy frameworks. A similar pattern can be observed in the *"Electric Charges and Electrical Energy"* unit, which was absent in 2020 and 2021 but reappeared with up to 3 questions in 2025. Some units have been entirely removed from the exam scope over time. In particular, the units *"Reproduction, Growth, and Development in Humans," "Light and Sound,"* and *"Earthquakes and Weather Events"* appeared only in 2018 and were excluded in later years. This may reflect changes in the 8th-grade curriculum by the Ministry of National Education or the fact that these units are typically covered earlier in the school year, rendering them outside the exam scope. The *"Simple Machines"* unit was not included in certain years (e.g., 2020 and 2023) but generally appeared with two questions in other years. The recurring presence or absence of this unit suggests that it may be selectively targeted based on desired cognitive levels in the exam design. In summary, the subject distribution in High School Entrance System science exams has varied year to year, although certain units have maintained consistent importance. These trends offer valuable insights for both teachers' annual planning and students' exam preparation strategies.

Table 2 shows the distribution of High School Entrance System science questions according to the levels of Bloom's Taxonomy.

Tablo 2. Distribution of 2018 High School Entrance Exam Science Questions According to Bloom's Taxonomy Levels

	Cognitive Level	**Question Numbers**	**Justification**
2018	Understanding	1 9 10 14 16	- Identifying the correct visual representation of a DNA model by understanding the underlying rule - Recognizing the light refraction properties of lenses - Explaining an observation related to sound propagation through scientific principles - Associating earthquake risks with fault line positions - Describing the conditions required for a chemical reaction
	Application	2 7 11 13 15 17 18	- Matching the stages of cell division with a given real-life scenario - Identifying parts of a system that contribute to mechanical advantage - Recognizing behaviors that prevent electrical charging - Relating the effect of electric charges to the behavior of an electroscope - Matching element properties with the functions of a teapot - Determining appropriate variables by designing an experimental setup - Estimating temperature changes based on heat exchange
	Analysis	3 5 6 8 12 19	- Making a selection in an experimental scenario based on genetic differences - Establishing a relationship between global warming and sea level rise - Drawing conclusions from experimental data about genetic engineering - Analyzing the relationship between the dependent variable and inclined plane setups - Establishing a cause-effect relationship within a filtration system - Interpreting a graph to explain heat exchange between two substances
	Evaluation	4 20	- Critically assessing the validity of an experimental setup - Evaluating the accuracy of linking physical principles with everyday phenomena

2019	Understanding	1 7 9 14 15 18	- Matching individual numbers in a food chain using logical order - Identifying and explaining adaptation and mutualistic relationships - Explaining the interaction between surface charge and paint particles - Identifying a setup that provides mechanical advantage - Recognizing the type of simple machine that provides mechanical advantage - Interpreting variables in a controlled experiment
	Application	3 8 10 13 17 20	- Designing an experimental setup appropriate to its purpose - Applying knowledge of electric charges to different contexts - Relating pressure-surface area relationships using a graph - Associating Earth's position with seasonal temperature changes - Matching indicator properties with various solutions - Interpreting graphs to relate to properties of matter
	Analysis	2 4 6 11 12 16 19	- Drawing conclusions from differences in nucleotide sequences - Comparing the role of fungi with other decomposers in an ecosystem - Interpreting inheritance experiment results and making genotype predictions - Observing experiments testing the relationship between depth and pressure - Drawing conclusions about hypothesis validity from electroscope observations - Distinguishing whether observations are chemical or physical changes - Classifying elements in a table based on atomic number and mass
	Evaluation	5	- Critically evaluating the appropriateness of applications
2020	Understanding	1 3 5 9 15 16	- Interpreting the fundamental characteristics of DNA structure - Drawing inferences regarding the DNA pairing process - Understanding the interaction between genes and environment - Distinguishing between weather events and climate concepts - Associating depth-pressure relationships with real-life examples - Identifying controlled variables in an experiment
	Application	2 8 10 11 12 13 14 18 20	- Accurately planning and interpreting genetic crosses - Applying the outcomes of genetic engineering to daily life scenarios - Interpreting graphs in relation to Earth’s movements - Applying the relationship between force and pressure to a physical example - Selecting appropriate graphs related to the transmission of sunlight - Identifying experimental setups suitable for observing solid pressure - Interpreting outcomes from a liquid pressure experiment - Applying periodic table knowledge to element classification - Using pH knowledge to explain observed color changes
	Analysis	4 6 7 17	- Evaluating genetic predictions based on a given result - Analyzing and interpreting the relationship between genes and floral organs - Evaluating and interpreting the natural selection process - Inferring from chemical change processes
	Evaluation	19	- Making judgments and conclusions regarding the chemical reaction of substance L

2021	Remembering	11	- Recalling fundamental information used to construct climate data
		16	- Knowing the basic structure and organization of the periodic table
	Understanding	1	- Interpreting the structural elements of DNA
		5	- Understanding gene transfer applications
		6	- Interpreting energy transfer within food chains
		8	- Explaining the nitrogen cycle and its agricultural contributions
		14	- Explaining equilibrium conditions and required forces
		17	- Drawing conclusions based on chemical changes
		18	- Explaining the effects of acid rain using pH knowledge
	Application	3	- Determining the outcome of genetic crosses based on ratio knowledge
		9	- Evaluating the implementation of a principle in a given example
		12	- Understanding the relationship between force and pressure in liquids
		15	- Determining equilibrium outcomes based on force-distance relationships
		20	- Making inferences by associating phase change knowledge with graphs
	Analysis	2	- Analyzing phenotypic results of genetic crosses
		7	- Inferring photosynthesis factors by interpreting graphs
		10	- Predicting seasons using given information
		13	- Comparing pressure-force relations via experimentation
	Evaluation	4	- Making judgments regarding heredity based on experimental observations
		19	- Assessing the relevance of experimental variables to the intended objective
2022	Remembering	16	- Recalling the fundamental positional information on the periodic table
	Understanding	1	- Interpreting the DNA replication model
		3	- Understanding the effect of environmental factors on gene expression
		4	- Classifying real-life examples of applications
		7	- Making inferences from a carbon cycle diagram
		20	- Explaining heat exchange related to phase changes of matter
	Application	6	- Determining variable relationships in experimental setups
		9	- Inferring from geographical location and seasonal knowledge
		12	- Evaluating the relationship between force and work in simple machines
		14	- Determining electron positions by relating charge movement
		18	- Eliminating based on indicators and solution types
	Analysis	2	- Evaluating inheritance results through genetic crosses
		5	- Drawing cause-effect conclusions from graphs
		10	- Investigating surface-pressure relationships using experimental design
		11	- Explaining liquid pressure based on experimental observations
		13	- Assessing lever equilibrium and force-distance relations
		15	- Interpreting charge conditions based on experiment
		17	- Analyzing chemical changes based on observation
	Evaluation	8	- Judging the ecological impact of certain behaviors
		19	- Interpreting and evaluating specific heat-related experimental results

2023	Understanding	2 5 7 8 13 18	- Interpreting the relationship between DNA structure and related concepts - Explaining the impact and consequences of mutations - Describing and interpreting the process of gene therapy - Associating an organism's feeding habits with environmental context - Explaining given scenarios using knowledge of pressure - Distinguishing between physical and chemical changes
	Application	1 3 9 10 14	- Applying genetic cross knowledge to new situations - Applying knowledge of DNA pairing to a model - Matching geographical location with seasonal information - Applying directional knowledge based on shadow length data - Predicting measurement outcomes using pressure concepts
	Analysis	4 6 11 12 15 17 20	- Analyzing genotypes based on experimental results - Evaluating environmental effects using experimental data - Distinguishing between weather phenomena and climate concepts - Inferring the relationship between weight and surface area from experimental observation - Interpreting graphs and relating them to physical states - Assessing element positions in the periodic table - Explaining color change using pH knowledge
	Evaluation	16 19	- Selecting the correct experimental design - Identifying evidence for a chemical change
2024	Understanding	1 3 7 16 17	- Understanding the relationships among DNA, gene, and chromosome models - Interpreting the logic behind cloning and distinguishing between sexual and asexual reproduction - Explaining and comprehending the nitrogen cycle - Making generalizations using elements in the periodic table - Explaining the concept and properties of compounds
	Application	6 8 10 13	- Predicting outcomes by altering the conditions required for photosynthesis - Applying global warming countermeasures to real-life scenarios - Interpreting pressure application based on pipette observations in an experimental setup - Establishing relationships among parts in a pulley system
	Analysis	2 4 5 9 11 12 14 15 18 19 20	- Eliminating possibilities using knowledge of inheritance - Evaluating and inferring the phenotypic effects of mutations - Interpreting and comparing positions of organisms in an ecosystem pyramid - Drawing climatic conclusions using map and seasonal knowledge - Testing liquid pressure hypotheses through experimental data - Interpreting the impact of applied force on a system - Analyzing electrical charging using an experimental setup - Solving repulsion/attraction situations between charged objects - Examining and inferring the effects of acids and bases on different materials - Identifying and comparing variables that affect heat change - Interpreting the melting process of matter through a graph

2025	Understanding	1	- Interpretation of a DNA pairing model
		2	- Inference based on the results of a genetic cross
		6	- Selecting the correct interpretation from a nitrogen cycle diagram
		11	- Interpreting the relationship between force and motion
		13	- Explaining the functioning of a device using the logic of electrical charging
		15	- Classifying examples of energy transformations
		16	- Interpretation of the periodic table system
		17	- Differentiating between physical and chemical changes
		20	- Making inferences related to phase change temperatures
	Application	5	- Predicting experimental outcomes based on photosynthesis knowledge
		8	- Designing experimental setups through inference
		9	- Interpreting variables that affect physical conditions
		12	- Identifying ways to reduce force in simple machines
	Analysis	4	- Analyzing the relationships between organisms in a food web
		7	- Interpreting graphs and establishing cause-effect relationships
		10	- Determining the hemisphere based on data tables
		14	- Determining the charge state from electrical interaction patterns
		18	- Comparing pH levels based on observed color changes
		19	- Inferring the relationship between temperature and mass from heat exchange
	Evaluation	3	- Drawing biological adaptation inferences based on experimental results

When the science questions in the High School Entrance System (LGS) are evaluated based on the cognitive levels of the Revised Bloom's Taxonomy, it is observed that out of a total of 160 questions, 51 fall under the "Analysis" level, 50 under the "Understanding" level, 45 under the "Application" level, 11 under the "Evaluation" level and 3 under the "Remembering" level. Each question has been categorized by year, with detailed justifications provided for its assigned cognitive level.

Remembering Level: No questions were asked at this level in 2018, 2019, 2020, 2023, 2024, or 2025. Only two questions in 2021 and one in 2022 were classified at this level. This suggests that the High School Entrance System aims not only to assess factual knowledge but also to measure students' abilities to process and interpret information.

Understanding Level: Each year, between 5 and 9 questions were classified under understanding. These questions were designed to assess students' comprehension of relationships between scientific concepts, their ability to establish cause effect connections, and to explain processes. This level was particularly used in abstract topics such as genetics, matter, and natural phenomena. The High School Entrance System clearly prioritizes ensuring that students grasp the meaning behind knowledge, not merely recall it.

Application Level: From 2018 to 2025, application-level questions averaged six per year. The highest number (9 questions) appeared in 2020, and the lowest (4 questions) in 2024 and 2025. These questions evaluated students' abilities to interpret experimental results, analyze graphs, and apply scientific knowledge in practical contexts thus measuring real life transfer of learning.

Analysis Level: In 2024, the number of analysis-level questions peaked at 11, indicating a shift toward higher order cognitive skills. The High School Entrance System is placing growing importance on data interpretation, comparison, and inference-making. These questions require students to extract meaning from data, graphs, experiments, and written texts.

Evaluation Level: This level was generally represented by 1-2 questions per year, though no such questions appeared in 2024. Evaluation-level items assess students' critical thinking and scientific decision-making skills. Despite their importance, such questions remain underutilized.

Creating Level: No questions have been categorized at this level during the entire eight year period. Creating-level skills (e.g., designing experiments, generating novel solutions) are often assessed through project-based evaluations, which may not align with the multiple-choice format of the exam.

The distribution of questions across taxonomy levels has been found to be non uniform and inconsistent in proportion. Given that the evaluation and creating levels form the foundation of scientific inquiry, reasoning, and innovation, the inclusion of more questions targeting these levels could increase the exam's discriminative power. Despite the 2018 science curriculum's stated intention to emphasize higher order cognitive skills, the majority of questions in practice have targeted lower order levels an outcome that merits critical attention. The analysis indicates that the exam is insufficient in assessing the full range of cognitive levels outlined in the Revised Bloom's Taxonomy. To ensure valid assessments, questions should be more evenly distributed across taxonomy levels.

An examination of yearly average correct response rates suggests that students struggle more with lower-order cognitive tasks than higher order ones. They face significant challenges in reading comprehension, integrating learned concepts, and interpreting existing knowledge. Therefore, in order to effectively foster higher-order thinking, foundational competencies especially those involving understanding must first be developed. If students cannot comprehend or interpret information, they will not be able to successfully analyze, synthesize, or evaluate that information. The lack of success may also stem from the structure of the exam itself, in addition to its cognitive imbalance. Since the High School Entrance System is administered once a year with no make-up opportunity, and medical exemptions are often not accepted, the pressure it places on students can negatively impact performance. In contrast, university entrance exams offer a chance to retake the exam, whereas 13-14 year old students face strict rules and greater anxiety, limiting their ability to perform optimally.

Although the High School Entrance System exam format was redesigned to reduce rote memorization and promote thinking, creativity, and inquiry, its multiple choice structure restricts the ability to assess creating-level skills, and limits even evaluation level assessments. The absence of open ended items prevents the inclusion of synthesis level questions. This ultimately means that 21st-century skills such as creativity are not being adequately measured. A key contribution of this study is to raise awareness among exam developers about this gap. Exams and questions that do not aim to measure creative thinking are inadequate for accurately selecting students. If creativity is not assessed, students with original ideas cannot be identified, undermining the fairness and effectiveness of the selection process.

Recommendations

- Students should practice data analysis, graph interpretation, and integrating multiple information sources.
- Multi-dimensional question-solving activities should be emphasized.
- Content should be studied not by rote learning but through relational thinking—students must **use**, **analyze**, and **interpret** what they learn.
- Learning environments should be designed to encourage students to ask **“why”** and **“how”**.
- Practice questions related to experiments, observations, and real-life applications should be reintroduced in anticipation of a possible increase in application-level questions.
- Even if creative questions are not yet part of the exam, students should be prepared for them through curriculum changes.
- Activities should be designed to integrate knowledge and thinking skills.
- Question diversity should be increased, with more emphasis placed on evaluation-level thinking.
- Open-ended, creativity-oriented questions should be incorporated into the education system.
- In the medium term, **new exam formats** capable of assessing “creating” skills should be explored.

- Curricula should systematically support the development of analysis and application skills in class.
- Every question type addresses different cognitive skills and individual student differences; thus, questions should match the nature of each unit.

References

Aslan, C. (2011). The effect of instructional practices aimed at improving questioning skills on pre-service teachers' ability to formulate questions. *Education and Science, 36*(160), 236–249.

Ayvacı, H. Ş., & Türkdoğan, A. (2010). An analysis of written questions in science and technology courses based on the revised Bloom's taxonomy. *Turkish Journal of Science Education, 7*(1), 13–25.

Başol, G., Yıldız, E., & Tutkun, M. İ. (2021). An examination of mathematics questions in the scholarship and boarding examination according to Bloom's taxonomy. *Journal of Civilization Educational Research, 5*(2), 1–17.

Çiftçi, B., & Aydın, A. (2023). Identification of metaphors and analogies in the 6th grade science textbook. *Journal of the Turkish Chemical Society, Section C: Chemical Education, 8*(1), 31–48. https://doi.org/10.37995/jotcsc.1203201

Demiröz, B., & Ertem, İ. S. (2022). An evaluation of unit assessment questions in elementary school science textbooks according to the cognitive process dimension of the revised Bloom's taxonomy, question types, and subject areas. *Maarif Schools International Journal of Educational Sciences, 6*(2), 32–55. https://doi.org/10.46762/mamulebd.1178806

Dindar, H., & Demir, M. (2006). An evaluation of fifth-grade teachers' science exam questions based on Bloom's taxonomy. *Gazi University Journal of Gazi Educational Faculty, 26*(3), 87–96.

Ekinci, O., & Bal, A. P. (2019). An evaluation of the 2018 LGS mathematics questions in terms of learning domains and the revised Bloom's taxonomy. *Muş Alparslan University Journal of Social Sciences, 7*(3), 9–18. http://dx.doi.org/10.18506/anemon.462717

Güleryüz, H., & Erdoğan, İ. (2018). An evaluation of middle school science exam questions according to Bloom's cognitive domain taxonomy: The case of Muş province. *Anemon Muş Alparslan University Journal of Social Sciences, 6*(1), 43–49. http://dx.doi.org/10.18506/anemon.354846

Gündüz, Y. (2009). An analysis of 6th, 7th, and 8th grade science and technology questions in terms of assessment tools and Bloom's cognitive domain taxonomy. *Journal of Yüzüncü Yıl University Faculty of Education, 6*(2), 150–165.

Güven, Ç., & Aydın, A. (2017). An analysis and evaluation of 7th grade science and technology curriculum questions in terms of the revised Bloom's taxonomy. *Atatürk University Kazım Karabekir Faculty of Education Journal, (35)*, 223–233.

Karasar, N. (2019). *Scientific research method* (34th ed.). Nobel Publishing.

Marbach, G., & Sokolove, P. G. (2000). Good science begins with good questions. *Journal of College Science Teaching, 30*(3), 192–195.

Ministry of National Education. (2018). *Science curriculum (primary and middle school 3rd–8th grades)*. MoNE Publications.

Şad, S. N., & Şahiner, Y. K. (2016). Student, teacher, and parent perspectives on the Transition from Basic Education to Secondary Education (TEOG) system. *Elementary Education Online, 15*(1), 53–76. https://doi.org/10.17051/io.2016.78720

Turgut, M. F., & Baykul, Y. (2021). *Measurement and evaluation in education* (15th ed.). Pegem Academy Publishing.

Tutkun, Ö. F., Demirtaş, Z., Arslan, S., & Gür Erdoğan, D. (2015). The general structure of the revised Bloom's taxonomy: Rationales and changes. *The Journal of Academic Social Science Studies, 32*(3), 57–62. http://dx.doi.org/10.9761/JASSS2684

Üner, S., Akkuş, H., & Kormalı, F. (2014). The cognitive level of questions in secondary school chemistry textbooks and exams and their relation to students' cognitive levels. *Ahi Evran University Journal of Kırşehir Faculty of Education, 15*(1), 137–154.

Yıldırım, A., & Şimşek, H. (2021). *Qualitative research methods in the social sciences* (12th ed.). Seçkin Publishing.

A NEW LOOK AT STEM: HYBRID STEM EDUCATION

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"It is time to move beyond the slogan and make STEM literacy an educational priority for all students" (Bybee, 2010, p.30).

Introduction

When the COVID-19 pandemic first affected the world in 2020, education was affected and online education practices began. This sudden transition in education provided limited time for both students and educators to comprehensively plan the learning process and receive adequate training (Sedaghatjou et al., 2021). With this urgent transition, the online learning process has focused on digital transformation. Therefore, elements such as field objectives, appropriate methods and cultural issues, which are among the basic factors in teaching and learning, were either assumed or planned incorrectly (Adedoyin and Soykan, 2020; Dhawan, 2020). Some courses are more difficult to convert to an online learning environment due to the lack of interaction in the face-to-face learning process. Courses such as STEM (Science, Technology, Engineering, and Mathematics) education, which are laboratory and practical, pose additional challenges especially in the transition to online teaching (Tigaa & Sonawane, 2020). The use of new technologies in education is a current theme in the 21st century teaching and learning process (Lemay, Doleck, & Bazelais, 2019). Understanding how these technological tools will promote deep learning is critical to enhancing the teaching and learning of STEM.

It may be possible to address issues such as energy efficiency, resource use, environmental quality, and hazard reduction, which are among the major problems of our age, with STEM education, which is an integrated curriculum approach. It can be said that the competencies needed for citizens to understand and address such issues are clearly related to STEM disciplines. STEM is expected to better equip the workforce in the fields of business and industry and

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global economic concerns. The need for a qualified workforce in the changing world has emerged as a result of studies conducted in STEM education (White, 2014). Many countries have taken the necessary reform movements in this direction for economic development and scientific content (National Research Council [NRC], 2012). The fact that the concept of STEM was emphasized by the National Science Foundation (NSF) in 1990 as being important in achieving economic growth in the United States of America (USA) has also drawn attention to this concept (Bybee, 2010). The 21st century. STEM education, which emerged in the USA, has spread rapidly throughout the world (Sanders, 2009). In our country, the Ministry of National Education (MEB), universities and scientists have carried out studies to adapt to the changing world and awareness has been created (Akgündüz et al., 2015; Çorlu, 2014; MEB, 2016). Science, Technology, Engineering and Mathematics are abbreviated as "STEM". STEM is an educational system that combines four different disciplines and aims to integrate four main disciplines based on application (Bybee, 2010). The aim of STEM education is not only to create knowledge but also to develop students' scientific thinking, critical thinking and problem-solving skills (Kuhn, 1993). STEM education is accepted as an "interdisciplinary" approach (Gonzalez and Kuenzi, 2012). An ideal STEM education enables students to understand how tools and mechanisms work and increases the use of technology (Bybee, 2010). STEM education is an important tool for understanding the world we live in and producing practical solutions. Students gain skills such as critical thinking, creativity, and social interaction with STEM education (Aşık, Küçük, Helvacı, and Çorlu, 2017). Economic development is also supported by technological products that emerge through the use of engineering in STEM education (Roberts, 2012). Therefore, countries that want to strengthen their national economies integrate STEM education into their curriculum and practices to produce innovative products (MEB, 2018; Next Generations Science Standards [NGGS], 2013). There are some purposes of STEM education (National Research Council [NRC], 2014). These purposes are to increase STEM literacy and the number of individuals who pursue a STEM career and to facilitate their entry into business life. As STEM literate individuals, they are expected to be aware of the disciplines of science, technology, engineering and mathematics, to acquire the basic concepts in these disciplines and to use these disciplines in daily life at a basic level (NRC, 2014). In other words, STEM literate individuals can be expressed as conceptual understanding, procedural skills and abilities to address STEM literacy. In other words, STEM literacy includes the integration of disciplines and their interrelated and complementary components. These are expressed as follows:

1- “To acquire scientific, technological, engineering, and mathematical knowledge and to use this knowledge to identify problems, acquire new knowledge, and apply this knowledge to STEM-related issues.

2- To understand the characteristic features of STEM disciplines as forms of human endeavor that involve processes of inquiry, design, and analysis.

3- To recognize how STEM disciplines shape our material, intellectual, and cultural worlds.

4- To engage with STEM-related issues and the ideas of science, technology, engineering, and mathematics as engaged, emotional, and constructive citizens” Bybee (2010, p.31).

In order to meet the need for STEM literate individuals, it is stated by researchers that STEM education programs should be integrated at all educational levels (Margot and Kettler, 2019). The first step in advancing STEM education is to clarify STEM literacy and determine it as the main objectives of school programs (Bybee, 2010). It is expected that reaching higher levels in STEM literacy will not be achieved quickly; it will take at least ten years. Table 1 shows the stages and goals of the action with a timeline.

Table 1. Ten years of action: Stages and goals (Bybee, 2010, p. 34)

Stages	**Timeline**
Launching STEM education reform	2 years
Scaling STEM reform	6 years
Anchoring STEM education reform	2 years
Evaluating STEM education reform	Continuous, major review every 10 years

STEM education should be prepared for students from preschool to higher education to provide interdisciplinary knowledge and skills related to life, and for a knowledge-based economy (NRC, 2011). Recently, it has been observed that STEM education is being continued for students at different levels of education. STEM education is not specific to a certain level of education, but can be provided at all levels of education from preschool to university education. STEM education encourages high school students to learn the knowledge and skills of different disciplines related to life together and prepares them for a knowledge-based economy (NRC, 2011).

Stem Education

The roots of STEM were discovered by NSF in the 1990s and used as a label for activities, policies or practices that include one or more of the STEM disciplines. The label, which first appeared as SMET, was later expressed as STEM to describe various NSF initiatives and programs. It is seen that most professionals related to STEM do not understand the acronym STEM. Most participants associated the acronym with “stem cell research” or plants (Keefe, 2010). On the other hand, it can be said that while most people generally interpret STEM to mean science and mathematics, it is rarely used to mean technology or engineering, and this is a problem that needs to be corrected. STEM is formed by combining the first letters of the English words Science, Technology, Engineering and Mathematics. When the literature is examined, it is seen that there is no clear definition of STEM. With the breadth of the field and the diversity of researchers, it has been seen that in addition to different definitions for STEM education, disciplines such as art and entrepreneurship have also been added (Gencer, Doğan, Bilen, & Can, 2019). It can be said that STEM education, which is named differently in the world, is named in Turkey as Science, Technology, Engineering, and Mathematics (BTMM) or Science, Technology, Engineering, and Mathematics (FeTeMM) as an abbreviation of the first letters. Yıldırım and Altun (2015) stated that “Science” should be interpreted as science, not science, and should be reformulated to become the STEM concept BiLTeMM (Science, Technology, Engineering, Mathematics).

When the letters representing each discipline of STEM are examined, the letter “S” corresponds to “Science”, which is the systematic study of the nature and behavior of the universe through observation, experimentation, and measurement, and the formulation of laws to explain these facts in general terms (White, 2014). The role of science is to contribute to scientific literacy by providing scientific inquiry in the context of the real world (Kelley & Knowles, 2016). Another letter, “T”, stands for (Technology). Technology is the creation and use of technical tools by utilizing various science subjects (e.g., industrial arts, engineering, applied science, and pure science). It also addresses their relationships with life, society, and the environment (White, 2014). STEM should mean a greater emphasis on technology in school programs. The letter “E” (Engineering) is the practical application of knowledge from pure sciences such as physics or chemistry, as in the construction of engines, bridges, buildings, mines, ships and chemical plants (White, 2014). Engineering includes two popular themes that are directly related to problem solving and innovation (Lichtenberg, Woock, & Wright, 2008). Although engineering is available in schools, it cannot be said that it is at a level that will contribute to society and create a career. Societies interested in innovation need to recognize and emphasize the T and E in STEM (Katehi, Pearson, & Feder, 2009). Although technology and engineering are included in school programs, the level covered in schools is quite low. It is important to scale technology and engineering courses and include them in science and mathematics education in a way that is appropriate. Finally, the letter “M” (Mathematics), Mathematics is the study of number, quantity, shape and space and the relationships between them with a special representation (White, 2014).

STEM education is not only focused on production but also includes 21st century skills. We can see the opportunity to apply 21st century skills with STEM. Students can develop 21st century skills such as adaptation, complex communication skills, social skills, non-routine problem solving skills, self-management/self-development and system thinking (NRC, 2010). While students have the opportunity to research with STEM education, teachers can also find time and opportunity for 21st century skill development. According to Tezel and Yaman (2017), STEM provides students with skills such as teamwork, communication, creative thinking, questioning, researching, producing and solving daily life problems by integrating knowledge and skills related to science, technology, engineering and mathematics disciplines. STEM education allows students to discover new things and better understand the relationships between events. It provides self-confidence and self-efficacy development through independent or collaborative work. It enables students to develop easier and shorter solutions to the problems they encounter. It increases students’ motivation to learn. Students gain an innovative perspective and gain design-oriented thinking skills. STEM education is an education used to prepare students with high-level talent and minds to solve global challenges and complex problems in a positive and productive way (Taylor, 2016). In an experiential environment, students develop their participation and understanding to become science and technology leaders with STEM (So, Ryoo, Park, & Choi, 2018).

The sub-discipline that STEM covers is a subject of disagreement in the literature. For example, Chen (2009) limits the definition to mathematics, natural sciences (physics, biology/agricultural sciences), engineering and computer science, while the US National Science Foundation includes life sciences (health professions, rehabilitation and nursing) and some social sciences (e.g. anthropology, psychology and sociology) as part of STEM with a broader definition (Green, 2007). It is debated whether STEM is multidisciplinary, where the four disciplines work together but maintain different disciplinary identities, or whether STEM is interdisciplinary or a new interdisciplinary beyond individual disciplines (Shanahan, Burke, & Francis, 2016). It is seen that there is no common understanding of the criterion even among university faculty members who are involved in more than one STEM project and research center (Breiner, Harkness, Johnson, & Koehler, 2012). STEM can be structured differently in schools by integrating STEM disciplines differently. The lowest level of integration between two or more disciplines is expressed as multidisciplinary (S-T-E-M). The subject is addressed from different perspectives of more than one discipline (Dugger and Fellow, 2011; Repko, 2008). The concept of interdisciplinary (SteM) is the next level. Concepts overlap and information is addressed in depth using different disciplines to solve problems (Dugger and Fellow, 2011; Repko, 2008). The highest level of integration is transdisciplinary. It is the level where the boundaries of the disciplines integrated on the main subject are blurred (E -> STM) (Dugger and Fellow, 2011; Repko, 2008). Transdisciplinarity should be used significantly in the learning process due to its effect on students' learning process (Beane, 1991).

The problem of how to integrate technology and engineering in situations where the level of education is low has caused these disciplines to be ignored and only science and mathematics to be integrated and addressed as S.t.e.M instead of S.T.E.M (Moore and Smith, 2014). Along with the process, the role of educators and pedagogical effects have revealed the concept of "STEM education" (Breiner et al., 2012). The most modern STEM understanding is the purposeful integration of various disciplines used to solve problems encountered in reality (Labov, Reid, and Yamamoto, 2010). The integrated STEM education model has also come to the fore with the understanding of the integration of engineering and technology with science and mathematics (Sanders, 2012). Integrated STEM models are shown in Figure 1.

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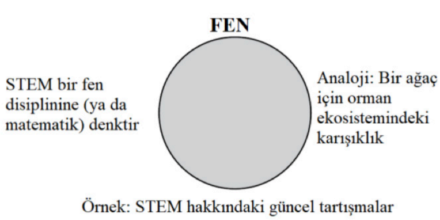
<td>Single-Disciplinary Model

STEM is equivalent to science or mathematics.
STEM is often used to mean science alone, but at times it also refers to physics or biology as standalone disciplines.
Analogy: Like a tree in a forest — isolated in concept.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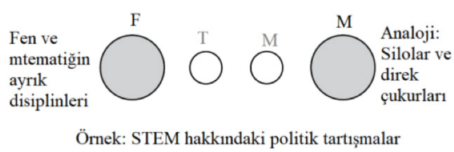
<td>STEM as a Reference for Science and Mathematics

STEM refers to both science and mathematics.
Analogy: Silos or isolated pits — separated domains.
Example: Ongoing political discussions around STEM.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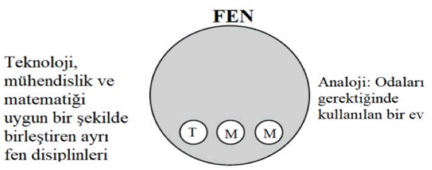
<td>Separate Science Disciplines Integrating Other Fields

STEM means science but also includes technology, engineering, or mathematics.
Analogy: A house with rooms — each discipline has its own space but contributes to the whole.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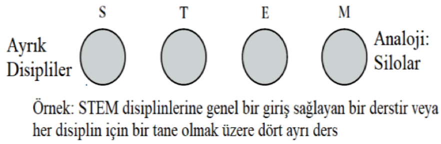
<td>Distinct Disciplines

STEM refers to a set of separate disciplines.
Analogy: Silos — taught independently.
Example: STEM subjects are delivered as individual courses.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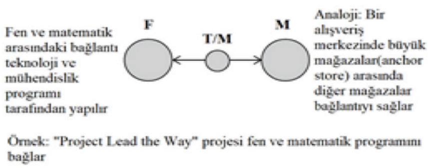
<td>STEM Connecting Science and Math with Engineering or Technology

STEM links science and mathematics with engineering or technology disciplines.
Example: ‘Project Lead the Way’ combines science with engineering curricula.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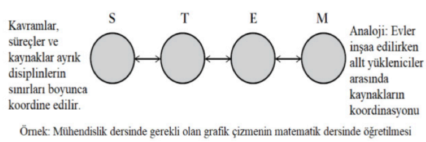
<td>Interdisciplinary Coordination

STEM is expressed as coordination across disciplines.
Analogy: Linked gears — synchronized disciplinary input.
Example: Engineering-driven science and math design courses.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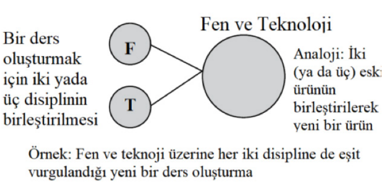
<td>Integration of Two or Three Disciplines

STEM integrates two or three disciplines together.
Analogy: Overlapping zones — interdisciplinary collaboration.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<td>Integrated Disciplines

STEM includes overlapping and complementary interdisciplinary elements.
Analogy: A complete and unified system.
Example: Teachers jointly design and deliver lessons across disciplines.

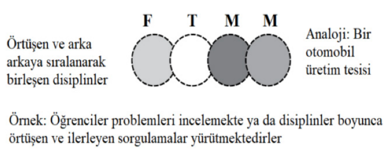
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Figure 1. Integrated STEM Education Models (Bybee, 2013; Gencer, et al., 2019).

The way and level of integration of the four disciplines that make up STEM may vary depending on the structure and content of the subject, the student and the school level (Vasquez, Sneider, & Comer, 2013). Levels of Discipline Integration (Vasquez et al., 2013)

Disciplinary: Concepts and skills are learned separately in each discipline.

Multidisciplinary: Concepts and skills are discussed separately in each discipline but are learned within a common theme.

Interdisciplinary: Interconnected concepts and skills are learned to deepen knowledge and skills in two or more disciplines.

Transdisciplinary: Knowledge and skills from two or more disciplines are applied to real-world problems and projects to help shape the learning experience.

In STEM, using design as a catalyst is an important way to bring STEM disciplines together on a common ground (Kelley & Knowles, 2016). Design provides a systematic and reflective approach to solving problems that exist in STEM disciplines. Engineering, on the other hand, provides the opportunity to find solutions to these problems and to solve problems in disciplines by creating connections between STEM subjects (Han, Kelley, & Knowles, 2023). Engineering design also provides the opportunity to conduct scientific research in the focus, in other words, science and inquiry, and since it creates a context for mathematical reasoning and modeling in the process, its use in science education enables the development of STEM education (English, 2022). When STEM disciplines are combined with complex STEM problems and inquiry, design becomes a common methodology in all STEM disciplines rather than just a feature of engineering (Hallström & Ankiewicz, 2023), that is; “Experimental design” for science, “technological design” in technology, “engineering design” in engineering and “design of mathematical algorithms and models” in mathematics enable the integration of disciplines (Mitcham, 2019).

Understanding of STEM in the World and Türkiye

In recent years, it has been observed that there is a tendency towards STEM studies both in the world and in our country. Because it is stated that the number of students receiving STEM education should be increased and contribute to the industry and industrial workforce of the countries (Wang, 2012). STEM education started in America and was seen in many countries after China, Korea and England (Yıldırım, 2016). It was initiated by the National Science Foundation-(NSF) in the USA in 1990. The studies carried out suggested that STEM education should be included in the curriculum, for example, it was included in the master's program at Virginia Tech University in 2003 and the first STEM graduates were given in 2005. STEM has now been seen as a solution for the country's economy in the USA and the studies have started to spread. STEM has now been supported by the state and continues to be so (Roberts, 2012; Bybee, 2010). In our country, low performances in the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Research (TIMSS) and the private sector have led to a shift towards STEM education. In our country, the Turkish Industrialists' and Businessmen's Association (TÜSİAD) organized a STEM education summit (TÜSİAD, 2014). While the connection between STEM and the workforce was expressed at this summit, the views of the business world and universities on this issue were evaluated. Attention was drawn to STEM-related activities in and out of school, and it was stated that individuals with STEM education were needed in the business world (Altan, Yamak, & Kırıkkaya, 2016). In addition, in-service trainings have been provided to teachers since 2013. Pilot applications were first implemented in schools determined by the Ministry of National Education. STEM centers were established in universities. The education system aims to raise individuals who have 21st century skills, can relate to STEM, and are interested in these fields. Teachers are aimed to increase their content and pedagogical knowledge with STEM. In order for the process to progress actively, STEM is expected to be integrated into the curriculum and students are expected to have the necessary competencies (Çepni and Ormancı, 2018). Steps have been taken in the context of engineering design skills and entrepreneurship in the middle school science curriculum in our country for STEM education (MEB, 2018). Although STEM education is not fully included in preschool, primary school and high school, it can be stated that the science course curriculum at the middle school level includes the STEM education approach. Engineering and design skills are included in the scope of field-specific skills in the program. Engineering and design skills include "Integrating science with mathematics, technology and engineering, by approaching problems from an interdisciplinary perspective, by reaching students to the level of invention and innovation, by using the knowledge and skills they have acquired to create products and develop strategies on how to add value to these products" (MEB, 2018, p. 10).

Hybrid Learning

It can be said that hybrid learning has attracted increasing attention among researchers in recent years. The rapid development of Information and Communication Technologies (ICT) in the 21st century and the necessity of digital technology and virtual learning after the COVID-19 outbreak have enabled the use of hybrid learning approaches in K-12 classrooms (Caplanova, Dunajeva, & Rodriguez, 2024). It shows that hybrid learning will provide student learning outcomes, motivation, and learning efficiency compared to face-to-face learning (F2F) (Li & Wang, 2022; Ma & Lee, 2021). Hybrid learning combines the advantages of synchronous and asynchronous discussion environments that help increase the quality of face-to-face education to a high extent (Lapitan, Tiangco, Sumalinog, Sabarillo, & Diaz, 2021). Hybrid learning provides learners with time and space flexibility with synchronous and asynchronous learning environments, while offering the aspects of interaction and emotional richness in face-to-face learning. Various models have been proposed for hybrid learning, such as reverse learning and computer-assisted learning. Hybrid learning is the combination of face-to-face learning with online learning (Graham, 2006, 2009). This definition emphasizes the duality seen in hybrid learning between face-to-face learning and virtual learning provided through computers. Garrison and Kanuka (2004) specifically emphasized the element of integrating both online and face-to-face education in hybrid learning classes. New developments in the implementation and use of hybrid learning continue (Halverson, Graham, Spring, Drysdale, & Henrie, 2014; Vo, Zhu, & Diep, 2017).

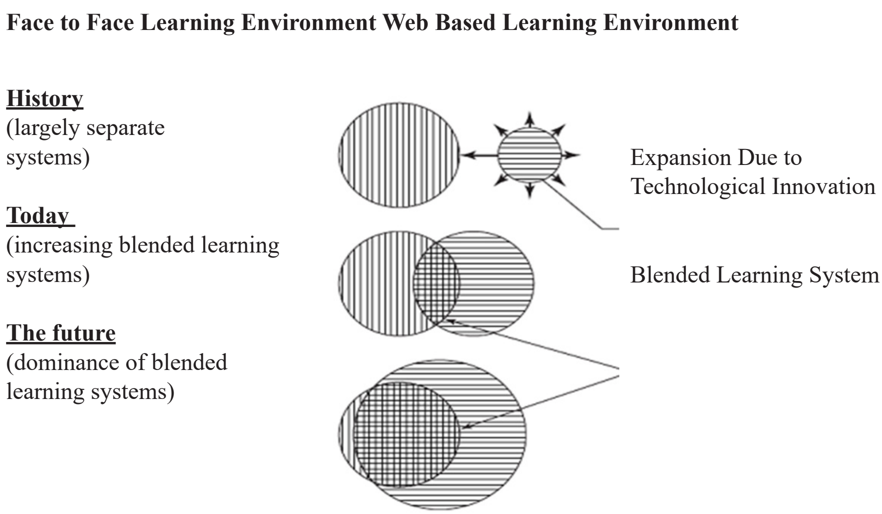

Figure 2. Development of face-to-face and web environments that enable the development of the blended learning system (Graham, 2006, p.6)

Although definitions of hybrid learning are not clear in the literature, there is a consensus on the combination of face-to-face and online education (Graham, 2006). In Figure 2, Graham (2006) has stated the past, present and future status of blended/hybrid learning. It is seen that face-to-face learning and web-based learning have not had any independent connection in the past. It is also seen that the use of web-based learning in the past was limited. When the future status of web-based learning is examined, it is seen that web-based learning is becoming increasingly widespread and will be dominant in a way that will include face-to-face learning. The aim in hybrid learning is to find a harmonious balance between online access to information and face-to-face interaction (Osguthorpe and Graham, 2003). However, more time is spent in hybrid courses than in traditional face-to-face courses (Means, Toyama, Murphy, & Baki, 2013). Educators have stated that when an online component is added to traditional courses, it causes a syndrome called the "course and a half" syndrome (Garrison & Vaughan, 2008). Researchers argue that in order to prevent these difficulties, decisions about which course, face-to-face or online, is most appropriate for achieving student learning outcomes, and the proportion of time to be spent in both courses are made without prior planning, and a course needs to be fundamentally re-planned. This type of new design results in what Graham (2006, p. 13) calls a "transformational blend" in which "learners construct knowledge through dynamic interactions." According to Graham, blends provide the same learning opportunities as the traditional form of a course but through different methods, providing greater access to learning or flexibility in learning, or blends that enhance the learning experience by creating additional online resources.

Components of Hybrid Learning Environments

In hybrid learning, the balance between face-to-face and online learning is important in the learning and teaching process (Osguthorpe and Graham, 2003).

Face-to-Face Learning Environment

A learning environment where educators communicate with students face-to-face in the classroom and the learning process is structured within the classroom. In face-to-face learning, educators and students interact simultaneously and share the same environment. Face-to-face learning environments have advantages and disadvantages. For example, identifying and eliminating deficiencies in learning in the classroom can be expressed as an advantage (Ellis, 2001). As a disadvantage, students who cannot attend face-to-face education for any reason will not have the chance to retake this course.

Online Learning Environment

Online learning environments offer two different learning environments: synchronous and asynchronous. A class where teachers and students are in the same environment at the same time using various tools and equipment can be described as a synchronous learning environment. Asynchronous learning environments are learning environments where students can start and finish whenever they want, meaning they do not have to be in the same virtual environment at the same time. Online learning environments are individualized learning that includes aspects such as autonomy, flexibility, and the use of multiple information and communication technologies compared to face-to-face learning environments (Lust, Elen, & Clarebout, 2013)

Hybrid Learning and Stem Education

Although there is no consensus on the concept of STEM, research on approaches that encourage improvements in STEM teaching and learning is desired (Brown, 2012). Researchers state that the number of students studying STEM subjects in higher education has decreased. Some of the reasons for this decrease are; weak teaching, lack of academic support (Yarker & Park, 2012), uninteresting and unappealing teaching practices (Dobson, 2014; Marginson, Tytler, Freeman, & Roberts, 2013). STEM needs to be taught "in a more enriching and engaging way, and [sometimes] interdisciplinary to keep curiosity alive" (Yarker & Park, 2012, as cited in Jayarajah, Saat, & Rauf, 2014, p. 156). Considering all these reasons, there is a need for STEM to shift towards student-centered approaches (Marginson, et al., 2013) and academic support should be provided for better teaching of STEM (Prinsely & Baranyai, 2015). Researchers are looking for new pedagogical approaches and strategies to increase education, learning, and participation in STEM (Baldwin, 2009). As calls for improvement in STEM education intensify, many have turned to new pedagogical approaches and technology to improve learning outcomes and success (Watkins & Mazur, 2013). The use of new technologies in education is a current theme in the 21st century teaching and learning process (Lemay, Doleck, & Bazelais, 2019). Understanding how these technological tools will promote deep learning is critical to enhancing the teaching and learning of STEM.

We can say that hybrid learning has a significant impact on STEM education. Hybrid learning is encouraged in STEM education and its effect on student performance is seen to be significantly high (Vo, et al., 2017). In international studies on STEM, it can be said that hybrid STEM education has emerged as a new field. For example, when looking at the studies conducted in the literature, it is seen that there are studies on how to provide STEM education in hybrid education environments (Van den Bogaart, Drijvers, & Tolboom, 2017; Naser, Halili, & Razak, 2021), the effect of hybrid STEM education on academic success (Antonopoulos et al., 2018; Seage & Türegün, 2020), and the effect of hybrid STEM education on STEM interest (Ardianti, Yahya, & Fitrianto, 2020). One of the reasons why hybrid learning affects students is its capacity to increase students' success in projects and assessments in STEM education (Seage & Türegün, 2020). Students in hybrid learning environments perform better than students in traditional learning environments (Seage & Türegün, 2020). Although it is widely accepted that STEM needs reform, there is a lack of literature on how this change can be made (Dolan, et al., 2016). Online and face-to-face educational activities, i.e. hybrid learning, are seen as an approach that hopes to transform STEM education. In hybrid learning, students are observed to perform better than traditional or online-only learning, and there is a decrease in students' dropout behavior (Moskal, Dziuban, & Hartman, 2013). It is stated that students in STEM courses can benefit more from hybrid learning opportunities compared to face-to-face learning and non-STEM-related courses (Vo, et al., 2017). It is seen in the literature that various negative consequences of using STEM only online are expressed (Maloy, Edwards, & Anderson, 2010; Chen, Bastedo, & Howard, 2018). These negativities have caused hybrid learning environments to be preferred more in STEM education (Norberg, Dziuban, & Moskal, 2011). Research shows that hybrid learning has positive effects on learning outcomes (Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014; Drysdale, Graham, Spring, & Halverson, 2013; Means et al., 2013; Larson & Sung, 2009; Tamim et al., 2011). Hybrid learning can also improve the needs of STEM students because increased participation, collaboration, and time spent on task have the potential to create a more positive and interactive learning environment (Drysdale et al., 2013; Means et al., 2013; Martín-Martínez et al., 2020; Spanjers et al., 2015). Collaborative or problem-based learning are effective teaching and learning approaches to engage students in hybrid learning (Keengwe and Kang, 2013; Stockwell, et al., 2015; Yeh, et al., 2011). It is argued that making the education system less dependent on location and time will be more effective (Raes, et al., 2020; Spanjers et al., 2015; Yapici and Akbayin, 2012). The learning styles that occur in hybrid learning environments of Chaeruman and Maudiarti (2018) as the "Hybrid Learning Quadrilateral" are explained in Figure 3. Synchronous learning is expressed as face-to-face and virtual, while asynchronous learning is expressed as self-directed and collaborative asynchronous learning.

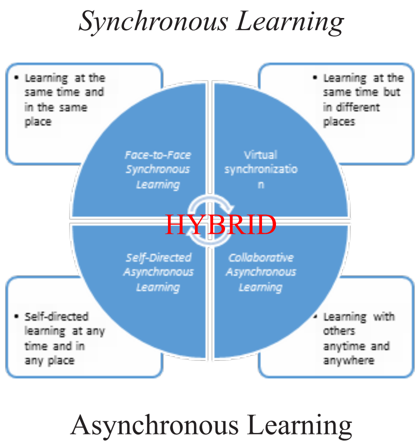

Figure 3. Hybrid Learning Quadrilateral (Chaeruman and Maudiarti, 2018, p.3)

According to Chaeruman and Maudiarti (2018, p. 3-4), synchronous and asynchronous learning environments are explained below. In addition, the activities that can be done in these learning environments are explained in Table 2.

Table 2. Learning Activities Option (Chaeruman and Maudiarti, 2018, p.4)

Hybrid Learning Environment			
Simultaneous Learning		**Asynchronous Learning**	
Face to Face Synchronous Learning	Virtual Synchronous Learning	Self-Directed Asynchronous Learning	Collaborative Asynchronous Learning
Learning Activities			
Lecture Discussion Application Workshop Seminar Laboratory practice Field trips … .	Virtual classroom Audio conferencing Video conferencing Web-based conferencing (webinar) …	Reading Watching (video, webcast) Listening (audio, audio) Online Study Simulation Drill and practice Test/exam Journal/publication (wiki, blog, etc.) ….	Participation in discussion forum Online homework (individual or group) Group research/ project Post sharing Practice learning community …

"Synchronous learning; 1- Face-to-face synchronous learning: It is a learning experience that takes place between the student and the learning resources at the same time and place. It can be used in the prototype development, testing and development stages related to the engineering part of STEM education. 2- Virtual synchronous learning: It is a learning experience that takes place between the student and the learning resources at the same time but in a different place. Asynchronous learning; 1- Collaborative asynchronous learning: It is a learning experience that takes place between the student and the learning resources with other resource persons at any time or place. 2- Self-directed asynchronous learning: It is a learning experience that takes place between the student and the learning resources at any time or place under their own pace and control. The three dimensions of the STEM approach; researching information, acquiring information and synthesizing information are realized with both synchronous and asynchronous learning environments (Lestari et al., 2021). Synchronous and asynchronous online learning tools and technologies (blogs, websites, etc.) can be used in the scientific inquiry part of STEM education, and in the face-to-face learning environment, the engineering design process can be carried out and hybrid learning and STEM education can be integrated.

As a result, this study aims to guide STEM educators and create a research agenda for hybrid STEM education as a new understanding. Studies conducted in the literature show that there is a need for pedagogical innovations in STEM education and that new searches are being made to meet this need. Hybrid STEM education can contribute to this search as a solution.

References

Adedoyin, O. B., & Soykan, E. (2020). Covid-19 pandemic and online learning: The challenges and opportunities. *Interact Learn Environ*, 1–13.

Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, B., Çorlu, MS, Öner, T., & Özdemir, S. (2015). *STEM education Turkey report*. İstanbul: Scala Publishing. Altan, E., Yamak,

H. & Kırıkkaya, H. (2016). A proposal for the implementation of STEM education approach in teacher education: design-based science education. *Trakya University Faculty of Education Journal*, 6(2), 212-232.

Antonopoulos, P., Archımandrıtıs, G., Karachrıstos, C. V., Lazarınıs, F., Stamatı, M., Stavropoulos, E. C., & Verykıos, V. S. (2018). Promoting stem education with arduino activities in a blended learning course. *INTE - ITICAM – IDEC, 2*, 444-448.

Ardianti, S., Yahya, F., & Fitrianto, S. (2020). The impact of using the stem education approach with blended learning to increase students' learning interest. *Indonesian Journal of STEM Education*, *2*(1), 1-10.

Aşık, G., Küçük, Z. D., Helvacı, B., & Corlu, M. S. (2017). Integrated teaching project: A sustainable approach to teacher education. *Turkish Journal of Education*, *6*(4), 200-215. https://doi.org/10.19128/turje.332731

Baldwin, R. (2009). The climate for undergraduate teaching and learning in STEM fields. *New Directions for Teaching and Learning, 2009*(117), 9–17. https://doi.org/10.1002/tl.340

Beane, J. (1991, October). The Middle School: The natural home of integrated curriculum. In *Integrating the curriculum* (pp. 9-13). Association for Supervision and Curreiculum Development.

Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. *Journal of Computing in Higher Education*, *26*(1), 87–122. https://doi.org/10.1007/s12528-013-9077-3

Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School science and mathematics*, *112*(1), 3-11.

Brown, J. (2012). The current status of STEM education research. *Journal of STEM Education: Innovations and Research, 13*(5), 7-11.

Bybee, R. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30–35.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities.* NSTA press.

Caplanova, A., Dunajeva, J., & Rodriguez, P. (2024). *Digital transformation in blended learning environments: EENEE analytical report*. Publications Office of the European Union. https://dx.doi.org/10.2766/061693]

Chaeruman, U. A., & Maudiarti, S. (2018). Quadrant of blended learning: A proposed conceptual model for designing effective blended learning. *Jurnal Pembelajaran Inovatif*, *1*(1), 1-5.

Chen, X. (2009). Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education. Stats in Brief. NCES 2009-161. *National Center for Education Statistics*.

Chen, B., Bastedo, K., & Howard, W. (2018). Exploring design elements for online stem courses: active learning, engagement & assessment design. *Online Learning*, *22*(2), 59-75.

Çepni, S., & Ormancı, Ü. (2018). *The world of the future*. In S. Çepni (Eds.), From theory to practice STEM+A+E education (pp. 1-37). Ankara: Pegem Publishing

Çorlu, MS (2014). Call for papers on STEM education. *Turkish Journal of Education*, 3(1), 4-10

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems*, 49(1), 5–22. https://doi.org/10.1177/0047239520934018

Dobson, I. A. (2014). *Staffing university science in the twenty-first century*. Australian Council of Deans of Science Victoria: Educational Policy Institute Pty Ltd. http://www.acds.edu.au/wp-content/uploads/sites/6/2015/05/ACDS-Science-Staffing-2014_August_Final.pdf

Dolan, E. L., Lepage, G. P., Peacock, S. M., Simmons, E. H., Sweeder, R., & Wieman, C. (2016*). Improving undergraduate STEM education at research universities: A collection of case studies*. Research Corporation for Science Advancement. https://www.aau.edu/sites/default/files/STEM%20Initiative%20Images/RCSA2016%20(4).pdf

Drysdale, J. S., Graham, C. R., Spring, K. J., & Halverson, L. R. (2013). An analysis of research trends in dissertations and theses studying blended learning. *The Internet and Higher Education, 17*, 90–100. https://doi.org/10.1016/j.iheduc.2012.11.003

Dugger, W., & Fellow, J. (2011). Evolution of STEM in the United States [Paper presentation]. *6th Biennial International Conference on Technology Education Research, Surfers Paradise*, Queensland, Australia. Retrieved on 21 January 2019 from http://www.iteea.org/Resources/PressRoom/AustraliaPaper.pdf

Ellis, A. (2001). Student-centered collobrative learning via face-to-face and asynchronous online communication: What's the difference?. *Meeting at the Crossroads*, 169- 178.

English, L. D. (2022). Multidisciplinary modelling in a sixth-grade tsunami investigation. Int. *J. Sci. Math. Educ*. 2022, 4. doi: 10.1007/s10763-022-10303-4

Garrison, D. R., & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education*. The internet and higher education, 7*(2), 95-105.

Garrison, D. R., & Vaughan, N. D. (2008). *Blended learning in higher education: Framework, principles, and guidelines.* San Francisco, CA: John Wiley ve Sons.

Gencer, A. S., Doğan, H., Bilen, K., & Can, B. (2019). Integrated STEM education models. *Pamukkale University Faculty of Education Journal,* 45(45), 38-55.

Gonzalez, H. B., & Kuenzi, J. J. (2012, August). *Science, technology, engineering, and mathematics (STEM) education: A primer*. Washington, DC: Congressional Research Service, Library of Congress.

Graham, C. R. (2006). Blended learning systems. *The handbook of blended learning: Global perspectives, local designs*, *1*, 3-21.

Graham, J. W. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology, 60*, 549–576. https:// doi.org/10.1146/annurev.psych.58.110405.085530

Green, M. (2007). *Science and engineering degrees: 1966-2004*. (NSF 07–307). Arlington, VA: National Science Foundation.

Hallström, J., & Ankiewicz, P. (2023). Design as the basis for integrated STEM education: A philosophical framework. In *Frontiers in Education* (Vol. 8, p. 1078313). Frontiers.

Halverson, L., Graham, C., Spring, K., Drysdale, J., & Henrie, C. (2014). A thematic analysis of the most highly cited scholarship in the first decade of blended learning research. *The Internet and Higher Education, 20*, 20–34. https://doi.org/10.1016/j.iheduc.2013.09.004

Han, J., Kelley, T., & Knowles, J. G. (2023). Building a sustainable model of integrated stem education: Investigating secondary school STEM classes after an integrated STEM project. *International Journal of Technology and Design Education*, *33*(4), 1499-1523.

Jayarajah, K., Saat, M. R. & Rauf, A. A. (2014). A review of science, technology, engineering and mathematics (STEM) education research from 1999-2013: A Malaysian perspective. *Eurasia Journal of Mathematics, Science and Technology Education,* 10(3), 155-163. http://dx.doi.org/10.12973/eurasia.2014.1072a

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington DC: National Academy Press.

Keefe, B. 2010. The perception of STEM: *Analysis, issues, and future directions. Survey*. Entertainment and Media Communication Institute.

Keengwe, J., & Kang, J. J. (2013). A review of empirical research on blended learning in teacher education programs. *Education and Information Technologies, 18*, 479–493. https://doi.org/10.1007/s10639-011-9182-8

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM education*, *3*, 1-11.

Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education, 77*(3), 319–337. **https://doi.org/10.1002/sce.3730770306**

Labov, J. B., Reid, A. H., & Yamamoto, K. R. (2010). Integrated biology and undergraduate science education: a new biology education for the twenty-first century?. *CBE—Life Sciences Education*, *9*(1), 10-16.

Lapitan Jr, L. D., Tiangco, C. E., Sumalinog, D. A. G., Sabarillo, N. S., & Diaz, J. M. (2021). An effective blended online teaching and learning strategy during the COVID-19 pandemic. *Education for Chemical Engineers*, *35*, 116-131.

Larson, D. K., & Sung, C. H. (2009). Comparing student performance: Online versus blended versus face-to-face. *Journal of Asynchronous Learning Networks, 13*(1), 31–42.

Lemay, D. J., Doleck, T., & Bazelais, P. (2019). Context and technology use: Opportunities and challenges of the situated perspective in technology acceptance research. *British Journal of Educational Technology, 50*(5), 2450–2465. https://doi.org/10.1111/bjet.12859

Lestari, H., Rahmawati, I., Siskandar, R., & Dafenta, H. (2021). Implementation of blended learning with a stem approach to improve student scientific literacy skills during the covid-19 pandemic. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 224.

Li, S., & Wang, W. (2022). Effect of blended learning on student performance in K-12 settings: A meta-analysis. *Journal of Computer Assisted Learning*, *38*(5), 1254-1272.

Lichtenberg, J., Woock, C., & Wright, M. (2008, October). *Ready to innovate: Are educators and executives aligned on the creative readiness of the U.S. Workforce?* (Report No. R-1424-08-RR). New York: The Conference Board.

Lust, G., Elen, J., & Clarebout, G. (2013). Regulation of tool-use within a blended course: Student differences and performance effects. *Computers & Education*, *60*(1), 385-395. https://doi.org/10.1016/j.compedu.2012.09.001

Ma, L., & Lee, C. S. (2021). Evaluating the effectiveness of blended learning using the ARCS model. *Journal of computer assisted learning*, *37*(5), 1397-1408.

Maloy, R. W., Edwards, S. A., & Anderson, G. (2010). Teaching math problem solving using a web-based tutoring system, learning games, and students' writing. *Journal of STEM Education: Innovations and Research*, *11*(1).

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons: International comparisons of science, technology, engineering and mathematics (STEM) education. Final report.* Melbourne: Australian Council of Learned Academies.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM education, 6*(1), 1-16.

Martín-Martínez, L., Sainz, V., & Rodríguez-Legendre, F. (2020). Evaluation of a blended learning model for pre-service teachers. *Knowledge Management & E-Learning, 12*(2), 147–164. https://doi.org/10.34105/j.kmel.2020.12.008

Means, B., Toyama, Y., Murphy, R., & Baki, M. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record*, *115*(3), http://www.academia.edu/download/43209482/%20study__online_and_blended_learning.pdf

Ministry of National Education Innovation and Educational Technologies General Directorate (2016). Ministry of National Education STEM Education Report. Ankara.

Ministry of National Education. (2018). *Science Course Curriculum (primary and secondary school 3rd, 4th, 5th, 6th, 7th and 8th grades)*. Ankara: State Books Printing House.

Mitcham, C. (2019). *Steps toward a philosophy of engineering: Historico-philosophical and critical essays*. Rowman & Littlefield.

Moore, T. J., & Smith, K. A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education: Innovations and Research*, *15*(1), 5.

Moskal, P., Dziuban, C., & Hartman, J. (2013). Blended learning: A dangerous idea? *The Internet and Higher Education*, *18*, 15–23. https://doi.org/10.1016/j.iheduc.2012.12.001

Naser, K. M. M., Halili, S. H., & Razak, R. A. (2021). Students'acceptance of using a flipped stem classroom engineerıng-based module. *juKu: Jurnal Kurikulum & Pengajaran Asia Pasifik*, *9*(1), 20-28.

National Research Council. (2010). *Preparing teachers: Building evidence for sound policy*. Committee on the Study of Teacher Preparation Programs in the United States. Washington, DC: The National Academies Press.

National Research Council [NRC]. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology*, engineering, and mathematics. Washington: National Academies Press.

National Research Council, Division of Behavioral, Board on Science Education, & Committee on a Conceptual Framework for New K-12 Science Education Standards (NRC) (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National academies press.

National Research Council. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: National Academies Press.

NGSS Lead States (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: The National Academies. https://nap.nationalacademies.org/catalog/18290/next-generation-science-standards-for-states-by-states

Norberg, A., Dziuban, C. D., & Moskal, P. D. (2011). A time-based blended learning model. *On the Horizon*, *19*(3), 207-216.

Osguthorpe, R. T., & Graham, C. R. (2003). Blended Learning Environments: Definitions and Directions. *Quarterly Review of Distance Education*, *4*(3), 227-33.

Prinsley, R. & Baranyai, K. (2015). *STEM skills in the workforce: What do employers want?* Occasional Papers, Issue 9, Office of the Chief Scientist, Australia. http://www.chiefscientist.gov.au/wp-content/uploads/OPS09_02Mar2015_Web.pdf

Raes, A., Detienne, L., Windey, I., & Depaepe, F. (2020). A systematic literature review on synchronous hybrid learning: Gaps identified. *Learning Environments Research, 23*(3), 269–290. https://doi.org/10.1007/s10984-019-09303-z

Repko, A. (2008). *Interdisciplinary research* (1st ed.). Los Angeles: SAGE.

Roberts, A. (2012). A justification for STEM education. *Technology and Engineering Teacher*, *71*(8), 1-4.

Sanders, M. E. (2012). Integrative STEM education as "best practice". In H. Middleton (Ed.), *Explorations of Best Practice in Technology, Design, & Engineering Education, 2,* 103-117. Griffith Institute for Educational Research, Queensland, Australia.

Seage, S. J., & Türegün, M. (2020). The Effects of Blended Learning on STEM Achievement of Elementary School Students. *International Journal of Research in Education and Science*, *6*(1), 133-140.

Shanahan, M., Burke, L. E. C., & Francis, K. (2016). Using a boundary object perspective to reconsider the meaning of STEM in Canadian context. *Canadian Journal of Science, Mathematics and Technology Education*, *16*(2), 129–139. https://doi.org/10.1080/14926156.2016.1166296

So, H. J., Ryoo, D., Park, H., & Choi, H. (2018). What constitutes Korean pre-service teachers' competency in STEAM education: Examining the multi-functional structure. *The Asia-Pacific Education Researcher*, *28*, 47-61. https://doi.org/10.1007/s40299-018-0410-5

Spanjers, I. A., Könings, K. D., Leppink, J., Verstegen, D. M., de Jong, N., Czabanowska, K., & Van Merriënboer, J. J. (2015). The promised land of blended learning: Quizzes as a moderator. *Educational Research Review*, *15*, 59–74. https://doi.org/10.1016/j.edurev.2015.05.001

Stockwell, B., Stockwell, M., Cennamo, M., & Jiang, E. (2015). Blended learning improves science education. *Cell, 162*(5), 933–936. https://doi.org/10.1016/j.cell.2015.08.009

Tamim, R., Bernard, R., Borokhovski, E., Abrami, P., & Schmid, R. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research, 81*(1), 4–28. https://doi.org/10.3102/0034654310393361

Taylor, B. (2016). Evaluating the benefit of the maker movement in K-12 STEM education. *Electronic International Journal of Education, Arts, and Science (EIJEAS)*, *2*.

Tezel, Ö., & Yaman, H. (2017). A compilation of studies on STEM education in Turkey. Journal of Education and Teaching Research, 6(1), 135-145.

Tigaa, R. A., & Sonawane, S. L. (2020). An international perspective: Teaching chemistry and engaging students during the COVID-19 pandemic. *Journal of Chemical Education, 97*(9), 3318–3321. https://doi.org/10.1021/acs.jchemed.0c00554

Turkish Industrialists' and Businessmen's Association (2014). Research on demands and expectations for workforce educated in STEM (science, technology, engineering and mathematics). Retrieved from https://tusiad.org/tr/yayinlar/raporlar/item/8054-stem-alaninda-egitim-almis- isgucune-yonelik-talep-ve-beklentiler-arastirmasi.

Van den Bogaart, T., Drijvers, P. H. M., & Tolboom, J. (2017). The design and use of open online modules for blended learning in STEM education. In *Proceedings of the 13th International Conference on Technology in Mathematics Teaching* (pp. 339-346). Universite de Lyon.

Vasquez, J., Sneider, C., & Comer, M. (2013). *STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics*. Portsmouth, NH: Heinemann.

Vo, H. M., Zhu, C., & Diep, N. A. (2017). The effect of blended learning on student performance at course-level in higher education: A meta-analysis. *Studies in Educational Evaluation*, *53*, 17-28.

Wang, H. (2012). *A new era of science education: Science teachers' perceptions and classroom practices of science, technology, engineering, and mathematics (STEM) integration*. Doctoral dissertation, University of Minnesota.

Watkins, J., & Mazur, E. (2013). Retaining students in science, technology, engineering, and mathematics (STEM) majors. *Journal of College Science Teaching, 42*(5), 36–41. Retrieved from https://www.jstor.org/stable/43631580

White, D. W. (2014). What is STEM education and why is it important. *Florida Association of Teacher Educators Journal, 1(*14), 1-9.

Yapici, İ. Ü., & Akbayin, H. (2012). The effect of blended learning model on high school students' biology achievement and on their attitudes towards the internet. *The Turkish Online Journal of Educational Technology, 11*(2), 228–237.

Yarker, M. B. & Park, S. (2012). Analysis of teaching resources for implementing an interdisciplinary approach in the K-12 classroom. *Eurasia Journal of Mathematics, Science and Technology Education,* 8(4), 223-232. http://www.ejmste.com/v8n4/eurasia_v8n4_yarker.pdf

Yeh, Y. C., Huang, L. Y., & Yeh, Y. L. (2011). Knowledge management in blended learning: Effects on professional development in creativity instruction. *Computers & Education, 56*(1), 146–156. https://doi.org/10.1016/j.compedu.2010.08.011

Yıldırım, B. (2016). Investigation of the effects of science, technology, engineering, mathematics (STEM) applications and mastery learning integrated into 7th grade science course. PhD Thesis, Gazi University Institute of Educational Sciences, Ankara. Yıldırım, B., & Altun, Y. (2015). Investigation of the effects of STEM education and engineering applications on science laboratory course. El-Cezeri Journal of Science and Engineering, 2(2), 28-40. Retrieved from https://dergipark.org.tr/en/pub/ecjse/issue/4899/67132.

THE EFFECT OF MICROLEARNING MODULES ON CONCEPTUAL CHANGE IN SCIENCE EDUCATION

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ABSTRACT

This study aims to reveal current trends, findings, and research gaps by examining international articles focusing on the use of microlearning in science education between 2010 and 2025 using document analysis methods. A systematic search conducted in the Web of Science, ERIC, EBSCOHost, ScienceDirect, and Google Scholar databases identified six qualified articles; these studies were compared in terms of subject, method, study group, data collection tools, analysis techniques, and reported effects. The findings showed that micro-learning-based lessons increased academic achievement in chemistry and physics, reduced conceptual misconceptions, and strengthened student participation. While students found short, visually interactive modules motivating, the need for laboratory simulations, experimental activities, and continuous feedback was emphasized for lasting learning in abstract and complex concepts. Studies have highlighted heterogeneous module durations, diversity in assessment tools, and technological access limitations as significant methodological challenges. While a general increase in self-efficacy was observed, inconsistent results were reported in the self-determination dimension, indicating the need for designs that support learner autonomy. In conclusion, microlearning has been shown to be a powerful strategy for science education that appeals to the digitally native generation with limited attention spans, but it must be supported by experience-based activities, low-bandwidth-friendly technological solutions, and holistic teaching ecosystems to achieve deep and sustainable understanding. The study recommends prioritizing longitudinal designs, scale standardization, and empirical evaluation of the in-class effectiveness of UI/UX-based prototypes in future research.

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Keywords: Science Education, Micro-Learning, Educational Technologies, Learning Motivation, Conceptual Understanding

INTRODUCTION

The digital age, in which the production of information is increasing at an extraordinary rate, has forced educators to re-examine their pedagogical paradigms and has directed them to develop new paradigms that can achieve learning in harmony with the changes brought about by technological developments, while reducing learners' attention spans to minutes or even seconds. These paradigms emerging in the digital age have been applied in science education (Bagır, Önal Karakoyun and Asiltürk 2022; Bulduk, 2024; Çelik, Önal Karakoyun and Asiltürk 2022; Çetinkaya, 2017; Önal Karakoyun and Asiltürk, 2021; Önal Karakoyun and Asiltürk, 2022) and mathematics (Cırık and Akpolat, 2024; Güneş, 2022; Nayıroğlu and Tutak, 2024; Polat and Tutak, 2025; Süzen et al., 2024) have provided important opportunities for the concretization of concepts and the more effective establishment of conceptual relationships in disciplines with abstract and complex structures. In this context, micro-learning, with its short-term, focused, and data-traceable structure, has rapidly become the "default" learning strategy not only in corporate training but also in primary and higher education.

Micro-learning is defined as a form of learning that involves short, intensive information modules focused on a single learning objective (Tayaz and Kapucu, 2024); its design is based on the spaced learning theory, which argues that spaced repetition between sessions supports long-term memory better than continuous batch learning (Taşkın and Aksoy, 2023). As Hug (2012) noted, the dimensions of time, content, curriculum, form, process, media, and learning model should be integrated in a holistic manner without limiting the content. Multi-modal approaches such as short texts, graphic transcripts, podcasts, and video clips (Taylor and Hung, 2022) have gained widespread use due to the ease of access on digital platforms (Dolasinski and Reynolds, 2020); particularly offering flexible, self-paced learning opportunities for adults with time constraints or those engaged in distance education (Fitria, 2022). This process, supported by Web 2.0 tools, reinforces learners' self-management, creativity, and decision-making skills (Alias and Razak, 2025; Denojean-Mairet et al., 2024), and by allowing content to be consumed quickly and repeated at desired times, it overcomes time constraints and encourages lifelong learning (Silva et al., 2025). Spaced repetition and periodic testing strengthen long-term memory (11); however, it is also emphasized that simply downsizing traditional lessons may reduce efficiency due to risks such as lack of focus, lack of deep thinking, and inability to establish logical structures, and that distractions in online environments may negatively affect the learning experience (Lee, 2023).

Systematic reviews in the literature show that the number of publications on microlearning has increased by an average of more than 25% each year since 2020 (Silva et al., 2025; Alias and Razak, 2023). Pioneering studies in science education literature first explored the potential of microlearning in physics classes. Sadaghiani's (2012) multimedia modules on electricity and magnetism shortened traditional class time but increased CSEM concept test scores by 16%, providing the first experimental evidence to guide the field. With the increasing use of mobile devices in the learning-teaching process, microlearning has rapidly spread to disciplines such as chemistry and biology. A study conducted with 9th-grade chemistry students reported an effect size of $d \approx 0.9$ for micro-lessons, demonstrating meaningful conceptual gains (Calixtro, 2023). A qualitative study conducted in the context of university physics showed that students described micro-learning as a tool that "makes the concept digestible" and increases motivation (Dwi Astuti et al., 2025). On the other hand, a recent study integrating AI-powered chatbots into micro-modules reported a 21% increase in higher-order thinking skills in high school biology (Wu and Yu, 2023).

The literature highlights three significant drawbacks of micro-learning, in addition to its positive impact on academic learning (Mercan et al., 2023; Monib et al., 2025; Pham et al., 2023; Veletsianos et al., 2022):

- heterogeneity in module duration and session count,
- diversity in scales used to measure conceptual change,
- risk of fragmented content creating "knowledge islands" that undermine the holistic scientific framework.

In particular, Cairel (2025) suggests that microlearning can create fragmented meaning when not designed in conjunction with comprehensive teaching strategies. Additionally, systematic reviews conducted using the PRISMA 2020 protocol highlight this methodological diversity, which hinders the comparison of effect sizes (Silva et al., 2025).

In this study, research on microlearning in science education was examined in terms of research topic, research method, study group, data collection tools, data analysis methods, findings related to microlearning, and results, and a number of recommendations were made for future research on the use of microlearning in science education.

Research Questions

The following questions were addressed in the study:

1. What research methods (method type, sample selection, data collection tools, and analysis techniques) have been preferred in the application and effects of the micro-learning approach in science education?

2. What are the findings presented by participants in the studies conducted regarding the effects of microlearning on science lessons, and what is the nature of these effects?

3. What research topics and approaches are recommended for the future to gain a deeper understanding of the effects of microlearning in science education?

MATERIALS AND METHODS

Document Analysis Method and Application Process

In this study, the document analysis method was adopted in order to determine the types of studies conducted on microlearning in science education and the relationships between these studies, as well as to guide future research (Minner et al., 2010; Baran & Bilici, 2015). Document analysis is defined as a method that involves the systematic scanning, selection, analysis, and evaluation of sources for a specific purpose (Karasar, 2005). This process was carried out in three main stages: determining the source search method and selection criteria, the search stage, and the analysis stage (Karaçam, 2013; Baran and Bilici, 2015). The details of the procedures carried out in the document analysis process are presented below:

Determining the Search Method and Selection Criteria

In the first stage of the research, specific criteria and keywords to be used in this regard were determined to select the articles and thesis studies to be examined using the document analysis method. Within the scope of the research, peer-reviewed articles published in journals and thesis studies available for international access that examined the effects of micro-learning in science education between 2010 and 2025 were considered. Due to the increase in studies on microlearning since the early 2010s, studies published during this time period were included in the research. Within the framework of these criteria, keywords relevant to the research topic were defined in Turkish and English to ensure access to national and international studies. For this purpose, Turkish expressions such as “mikro-öğrenme,” “fen ve mikro-öğrenme,” and “fen eğitiminde mikro-öğrenme” and English expressions such as “microlearning,” “science and microlearning,” and “microlearning in science education” were used in the search process.

Search Process

Within the scope of the research, ISI Web of Science, EBSCOHost, Science Direct, and ERIC databases, as well as the Google Scholar search engine, were systematically searched using the defined keywords to access articles focusing on microlearning. The YÖK National Thesis Center and ProQuest Dissertations & Theses Global platforms were used to access thesis studies. During the search process, the publications found were carefully examined in terms of title and content in order to eliminate studies unrelated to the research topic; only those suitable for the scope of the research were included in the study. As a result of this process, five article studies were included in the research; however, no national or international thesis study on micro-learning in science education could be found. In addition, the bibliographies of the selected studies were analyzed in detail to identify articles, papers, or thesis studies that could not be identified during the search process; however, no additional publications were found as a result of this review.

Considering that studies on micro-learning have recently begun to intensify and that these studies address disciplines such as science, cognitive sciences, and education together, the limited number of publications on the subject is to be expected. This interdisciplinary structure poses certain challenges due to the complexity of the research content and the novelty of the subject.

Analysis Process

The contents of the articles and theses included in the scope of the research were evaluated in various dimensions using a systematic approach. This evaluation was carried out within the framework of the research topic, research method used, study group, data collection tools, data analysis techniques, effects of the micro-learning method, and basic findings categories.

CONCLUSION AND DISCUSSION

The articles identified at the end of the screening process, which was carried out in accordance with the criteria comprehensively explained in the methodology section of the study, were examined in terms of publication year, author names, article title, and publication information, and the results are presented in Table 1.

Table 1. Articles investigating the effects of microlearning in science education

	Studies Published as Articles in International Journals		
	Year	Authors	Title of Study & Publication Details
1	2023	Lovelyn A. Calixtro	Effectiveness of Microlearning-based Lessons in Teaching Grade 9 Chemistry. *Universal Journal of Educational Research*, 2(4), 351-356.
2	2025	Irnin Agustina Dwi Asturi, Muhammad Japar, Basuki Wibawa	Physics Students' Perceptions of Microlearning: A New Approach in Education, *JIPF*, 10(1), 166-174.
3	2025	Jinky Cairel	Microlearning in Science Education: Bridging Knowledge Gaps or Creating Fragmented Understanding?. SSRN, 1, 1-13. http://dx.doi.org/10.2139/ssrn.5279757
4	2011	Homeyra R. Sadaghiani	Using Multimedia Learning Modules in a Hybrid-Online Course in Electricity and Magnetism. *Phys. Rev. Phys. Educ. Res.*, 7, 010102.
5	2022	Kieth John D. Galarosa, Denis A. Tan	Students' Academic Performance and Motivation in Physics Using a Microlearning Approach via Cybergogy. *Science International (Lahore)*, 34(2), 157-170.
6	2025	Asti Aulia Sari, Siti Nur Ayu,Zidny Manaasika	Development of UI / UX Based Microlearning to Prevant Misconception in Physics Learning with Computational Thinking Approach. *Sakaguru J. Pedagog. Creat. Teach*, 2(1), 71–80. https://doi.org/10.70211/sakaguru.v2n1.206

Table 1 summarizes six international studies investigating the effects of the microlearning approach in science education. Fifty percent of these studies (three studies) were published in 2025, reflecting the growing interest in this method in recent years. Additionally, 66.7% of the studies (4 studies) focused on physics education, indicating that microlearning is being extensively addressed in this field. These studies demonstrate that microlearning is an innovative approach in science education. Detailed information on the topics, methods, data collection tools, and study groups of the relevant articles is presented in Table 2, which follows the same order as Table 1.

Table 2. Study Topics, Methods, Data-Collection Instruments, and Study Groups

	Study Topics	Method & Data-Collection Instruments	Study Group
1	Evaluating the effectiveness of micro-learning–based lessons in improving Grade 9 students' academic performance in chemistry	Single-group pre-test–post-test quasi-experimental design; the dependent variable was measured before and after manipulation of the independent variable. A teacher-made 25-item multiple-choice pre-/post-test covering the Grade 9 chemistry curriculum (content validity established by expert review) was administered during the second quarter of the 2020–2021 academic year.	12 ninth-grade students
2	Investigating how the application of micro-learning strategies in physics education affects students' learning experiences and academic achievement through their perceptions	Qualitative research employing a descriptive design; data collected via open-ended questionnaires and semi-structured interviews.	30 university students
3	Examining the potential of micro-learning in science education to bridge knowledge gaps and the risk of fostering fragmented conceptions	Qualitative research with a descriptive design; data gathered through open-ended questionnaires and semi-structured interviews.	30 university students
4	Assessing the effectiveness of web-based Multimedia Learning Modules (MLMs) developed by the University of Illinois Urbana-Champaign Physics Education Research Group when used as pre-class assignments in a hybrid online electricity and magnetism course at California State Polytechnic University, Pomona	Controlled study: students in the experimental group watched MLMs before attending face-to-face sessions, reducing class time by one-third. Instruments included the Conceptual Survey of Electricity and Magnetism (CSEM), responses to in-class clicker questions, and student surveys on the usefulness of course components.	82 university students
5	Exploring Grade 9 students' academic performance and motivation in physics through a micro-learning approach within a cybergogy learning environment	Sequential explanatory mixed-methods design. Instruments: pre-test, post-test, retention test, motivation questionnaires, and semi-structured interviews for in-depth insights.	9 high-school students
6	Developing a UI/UX-based micro-learning environment, grounded in computational thinking, to prevent misconceptions in physics learning	Research-and-Development (R&D) method based on the Borg & Gall model, focusing on the product-design stage only. Instruments: literature review, identification of potentials and problems, and prototype design for thermodynamics content.	— (no participant group at this stage)

Table 2 summarizes the objectives, methods, and study groups of six articles examining the microlearning approach in science education, while Table 3 details the data analysis methods and effects of microlearning applications in these studies. The studies present findings indicating that microlearning enhances academic achievement in chemistry and physics education, improves student perceptions and learning experiences, reduces misconceptions, and is effective in hybrid learning environments. Data collected using various methods such as quasi-experimental, qualitative, mixed methods, and research-development were analyzed through pre-test/post-test, surveys, interviews, literature reviews, and prototype designs. The study groups consisted of high school and university students, and the data analysis methods in Table 3 show that these effects were evaluated statistically and qualitatively. This table highlights the multifaceted potential of microlearning in science education while revealing that different effects come to the fore depending on the application context.

Table 3. Data-Analysis Methods and Identified/Examined Effects of Micro-Learning Applications in the Reviewed Articles

	Data-Analysis Method	Identified/Examined Effects of Micro-Learning Applications*
1	Data were analysed using means and paired-sample *t*-tests.	Findings showed that micro-learning-based lessons significantly improved students' chemistry performance; post-test scores increased markedly compared with pre-test scores (mean difference = 7.95).
2	Responses were transcribed and examined through thematic analysis; themes relating to the effectiveness, benefits, and challenges of micro-learning were generated.	Results revealed that 80 % of students accurately understood micro-learning as a method delivering small, digestible content units and found it effective, motivating, and engaging for grasping physics concepts. Students nonetheless highlighted the need for more interactive, in-depth content for complex topics and called for solutions to technological-infrastructure and access problems.
3	Data were evaluated with thematic analysis; themes concerning the effectiveness, advantages, and limitations of micro-learning were identified.	Students perceived micro-learning as offering short, comprehensible chunks of information and found it largely effective, flexible, and motivating for understanding scientific concepts. However, they noted a need for deeper, more interactive materials for complex subjects and pointed to difficulties such as technological access and limited feedback.
4	Data were processed through normalised-gain calculations and comparative analysis of student responses.	Despite reduced classroom time, Multimedia Learning Modules (MLMs) did not negatively affect learning outcomes; indeed, they enhanced performance on conceptual tests and in-class discussions. Over 75 % of students regarded MLMs as effective for learning physics concepts; 90 % reported easy technical access, and 60 % preferred the hybrid format to traditional face-to-face instruction.

	Data-Analysis Method	Identified/Examined Effects of Micro-Learning Applications*
5	Academic-performance data were analysed with a two-tailed *t*-test; motivational data were examined via descriptive statistics and qualitative content analysis.	Students' initially low pre-test scores rose significantly on the post-test and retention test after the MCLE intervention. Motivation analysis showed gains in self-efficacy and reduced evaluation anxiety, with slight dips in intrinsic motivation, personal interest, grade motivation, and self-determination—yet overall motivation remained high. Qualitative data indicated that students viewed the MCLE as an interactive strategy facilitating physics learning.
6	Findings from the literature review were systematically evaluated.	Evidence suggested that a UI/UX-based micro-learning environment—featuring interactive, visual content developed in Figma—can ease comprehension of abstract physics topics such as thermodynamics and has potential to reduce misconceptions.

Table 4 shows that microlearning increases conceptual understanding, participation, and retention in chemistry and physics; it also provides flexibility through adaptation to individual learning speeds and visual support. However, experimental activities, continuous feedback, and reliable technological infrastructure are essential for deep understanding. While performance and overall motivation increase, sub-dimensions such as self-determination still need to be researched. While short, interactive, and adaptable modules appeal to the digital generation, comprehensive designs with enriched content and access opportunities are essential for a sustainable, inclusive impact.

COMMENTS AND RECOMMENDATIONS

The findings of the study reveal that microlearning-focused lesson designs significantly improve academic performance in chemistry and physics, reduce conceptual misconceptions, and motivate students with "small but concise blocks of information." however, students emphasized that micro content alone is insufficient when dealing with abstract and complex topics, and that sustained learning is achieved when supported by laboratory simulations, experimental applications, and continuous feedback loops. While a significant increase in self-efficacy was observed alongside performance improvements, a partial decline in the self-determination dimension points to the necessity of designs that reinforce learner autonomy. Additionally, technological infrastructure and access constraints—particularly low bandwidth and device diversity—have limited potential gains, highlighting the critical need for inclusive, offline-accessible, and low-data-consumption content designs. UI/UX-based microlearning prototypes have been found to have the potential to reduce errors in abstract concepts such as thermodynamics through visual interactive elements; however, since the long-term effects of these prototypes have not yet been empirically tested in the classroom, large-scale monitoring and evaluation studies have been recommended. When all the data is considered together, while microlearning is successful in leveraging short attention spans, the necessity of a comprehensive teaching ecosystem that integrates experience-based activities, continuous feedback, and accessible technological solutions while prioritizing learner autonomy becomes clear for sustainable and deep understanding.

REFERENCES

Alias, N. F., & Razak, R. A. (2025). Revolutionizing learning in the digital age: A systematic literature review of microlearning strategies. *Interactive Learning Environments,* 33(1), 1-21.

Alias, N. F., Abdul Razak, R. (2023). Exploring the pedagogical aspects of microlearning in educational settings: A systematic literature review. *Malaysian Journal of Learning and Instruction*, *20*(2), 267–294. https://doi.org/10.32890/mjli2023.20.2.3

Bagır, M., Önal Karakoyun, G., & Asiltürk, E. (2022). Views of science teachers on the use of artificial intelligence in education. *Internatıonal Onlıne Journal of Educatıonal Scıences*, 14(5), 1223-1234.

Bulduk, Ö. (2024). Fen bilimleri konu öğretimi ve öğrenimi ile ilgili öğretmen ve öğrenci ihtiyaçlarının belirlenmesi: Bir devlet ortaokulu örneği. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi*, 59, 205-239.

Cairel, J. (2025). Microlearning in Science Education: Bridging Knowledge Gaps or Creating Fragmented Understanding?. *SSRN*, 1, 1-13. http://dx.doi.org/10.2139/ssrn.5279757

Calixtro, L. A. (2023). Effectiveness of Microlearning-based Lessons in Teaching Grade 9 Chemistry. Universal Journal of Educational Research, 2(4), 351-356.

Cırık, İ., & Akpolat, T. S. (2024). Abdüktif düşünmenin k12 beceri geliştirme sürecindeki rolü: Matematik dersi Örneği. *Milli Eğitim Dergisi*, *53*(241), 519-542.

Çelik, R., Önal Karakoyun, G., & Asiltürk, E. (2022). Evaluation of middle school 7th grade science skill-based questions according to the revised bloom taxonomy. *International Online Journal Of Educational Sciences, 14*(3), 705-716.

Çetinkaya, M. (2017). Fen eğitiminde modelleme temelinde düzenlenen kişiselleştirilmiş harmanlanmış öğrenme ortamlarının başarıya etkisi. *Ordu Üniversitesi Sosyal Bilimler Araştırmaları Dergisi*, 7(2), 287-296.

Denojean-Mairet, M., López-Pernas, S., Agbo, F. J., & Tedre, M. (2024). A literature review on the integration of microlearning and social media. *Smart Learning Environments*, *11*(1), 46.

Dolasinski, M. J., & Reynolds, J. (2020). Microlearning: a new learning model. *Journal of Hospitality & Tourism Research*, *44*(3), 551-561.

Dwi Astuti, I.A., Japar, M., Wibawa, B. (2025). Physics students' perceptions of microlearning: A new approach in education. *Jurnal Ilmu Pendidikan Fisika*, 10(1), 166-174. http://dx.doi.org/10.26737/jipf.v10i1.6053

Fitria, T. N. (2022). Microlearning in teaching and learning process: A review. *CENDEKIA: Jurnal Ilmu Sosial, Bahasa Dan Pendidikan*, *2*(4), 114-135.

Güneş, F. (2022). The direct instruction model. *The Journal of Limitless Education and Research*, *7*(1), 1-39.

Hug, T. (2012). Microlearning. In *Encyclopedia of the Sciences of Learning* (pp. 2268-2271). Springer, Boston, MA.

Lee, Y. M. (2023). Mobile microlearning: a systematic literature review and its implications. *Interactive Learning Environments*, *31*(7), 4636-4651.

Mercan, G.,Varol Selçuk, Z., & Köseoğlu, P. (2023). Technological approaches in mathematics and science education: Microlearning. *Journal of Social Sciences and Education*, 6(Education Special Issue), 380-400.

Monib, W.K., Qazi, A., & Apong, R.A. (2025). Microlearning beyond boundaries: A systematic review and a novel framework for improving learning outcomes. *Heliyon*, 11, 1-29. https://doi.org/10.1016/j.heliyon.2024.e41413

Nayıroğlu, B., & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Educational Studies*, 11, 65-78. https://doi.org/10.33907/turkjes.1415591

Önal Karakoyun, G., & Asiltürk, E., (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure – Acidity/Basicity Relationship" Topic. *Acta Chimica Slovenica*, 68, 1-13.

Önal Karakoyun, G., & Asiltürk, E., (2022). The effect of heuristics on the reasoning of the pre-service science teachers on the topic of melting and boiling point. *Acta Chimica Slovenica,* 69(1), 60-72.

Pham, H.H., Nhu Nguyen, N.T., Hai, L.D., Nguyen, T.T., Nguyen, V.A.L. (2024). Science mapping the knowledge base on microlearning: using Scopus database between 2002 and 2021. *Journal of Research in Innovative Teaching & Learning,* 2024; https://doi.org/10.1108/JRIT-09-2023-0132

Polat, M., & Tutak, T. (2025). Interdisciplinary comparative analysis of science and mathematics teachers' level of technology use in teaching processes, their aims and problems encountered. *International Journal of Research in Teacher Education (IJRTE)*, 16, 34-48. https://doi.org/10.29329/ijrte.2025.1300.03

Sari, A. A., Ayu, S. N., & Manaasika, Z. (2025). Development of UI / UX Based Microlearning to Prevant Misconception in Physics Learning with Computational Thinking Approach. *Sakaguru J. Pedagog. Creat. Teach*, 2(1), 71–80. https://doi.org/10.70211/sakaguru.v2n1.206

Silva, E. S., Costa, W. P. D., Lima, J. C. D., & Ferreira, J. C. (2025). Contribution of microlearning in basic education: A systematic review. *Education Sciences*, *15*(3), 302.

Süzen, A.B., Tutak, T., İlhan, A., & Nayıroğlu, B. (2024). Teacher and student opinions on teaching four operations with ınteger numbers in 7th grade with counting stamps. *International e-Journal of Educational Studies,* 8, 142-156. https://doi.org/10.31458/iejes.1343835

Taşkın, G., & Aksoy, G. (2023). "Hibrit öğrenme modeli: Teorik bir bakış", *XVI. Uluslararası Eğitim Araştırmaları Kongresi*, 26-29 Ekim 2023, Sivas, Türkiye.

Tayaz, E., & Kapucu, S. (2024). Hemşirelik eğitiminde yenilikçi bir yaklaşım: Mikro öğrenme. *Ankara Yıldırım Beyazıt Üniversitesi Türkiye Sağlık Araştırmaları Dergisi*, 5(1), 30-36.

Taylor, A. D., & Hung, W. (2022). The effects of microlearning: A scoping review. *Educational technology research and development*, *70*(2), 363-395.

Veletsianos, G., Houlden, S., Hodson, J., Thompson, C.P., & Reid, D. (2022). An evaluation of a microlearning ıntervention to limit COVID-19 online misinformation. *Journal of Formative Design in Learning*, 6, 13-24. https://doi.org/10.1007/s41686-022-00067-z

TRANSITIONING FROM ECO-ANXIETY TO ECO-ACTION THROUGH EMOTION REGULATION STRATEGIES IN CLIMATE LITERACY

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SUMMARY

This section addresses the multi-layered nature of the climate crisis within a framework that spans from "eco-anxiety to eco-action." First, it emphasizes that increasing fossil fuel consumption and urbanization since the Industrial Revolution have raised global temperatures through greenhouse gas emissions into the atmosphere, a trend clearly confirmed by IPCC and NASA data. It then draws attention to the fact that climate change is not only an environmental issue but also a profound psychosocial problem, noting that chronic heat waves, water stress, and extreme weather events fuel a widespread form of anxiety known as "eco-anxiety" in societies. The study argues that emotion regulation strategies play a key role in transforming this anxiety into collective action rather than creating a sense of individual paralysis. Mindfulness, breathing exercises, and nature-based experiences have been shown to alleviate anxiety, while cognitive strategies such as reframing have been demonstrated in recent studies to increase participation in educational settings and support environmentally friendly behaviors. Summarizing the evolution of the international climate regime from Stockholm to Paris and Dubai, the necessity of social participation and local-scale adaptation policies for multilateral agreements to achieve concrete results is highlighted. In the context of Turkey, the implementation of the updated National Contribution Statement in line with the 2053 net zero target is linked to water-energy-agriculture integration, gradual carbon pricing, and just transition financing. In conclusion, the study proposes an intergenerational, inclusive roadmap that integrates psychological well-being-based approaches into policy design to strengthen climate literacy. In this way, eco-anxiety can

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be transformed from a source of stress that weakens society into a constructive motivation that triggers sustainable behavior.

Keywords: Science Education, Eco-anxiety, Emotion Regulation, Climate Literacy, Eco-action

INTRODUCTION

Factors such as increased fossil fuel use in production processes following the Industrial Revolution, rapid population growth, uncontrolled urbanization, and the destruction of natural habitats have led to serious environmental problems on a global scale (Akbulut and Kaya, 2021; Sezik and Dokuyucu, 2025; Soltekin et al., 2021). One of the most significant consequences of these factors is the accumulation of greenhouse gases in the atmosphere, which has caused global temperatures to rise and made climate change a critical issue (Türkeş, 2022; IPCC, 2023). Climate change is no longer just a problem for scientists or politicians; it has become a vital issue that deeply affects all segments of society and requires global cooperation (Filho et al., 2023; Mersinlioğlu Serin, 2025).

In recent years, the problems caused by climate change have led to environmental stress and anxiety, referred to as eco-anxiety, at various levels around the world. This situation affects individuals' quality of life and can be an obstacle to adopting sustainable lifestyles (Brophy et al., 2023; Clayton and Karazsia, 2020). In particular, directly experienced environmental crises such as disasters, droughts, and heat waves increase individuals' levels of anxiety about climate change (Kankawale and Niedzwiedz, 2023; Rothschild and Haase, 2023). In this context, the importance of emotion regulation strategies for managing eco-anxiety and transforming it into positive behavioral changes is increasingly recognized.

Emotional regulation strategies are psychological mechanisms that facilitate individuals' ability to manage negative emotions, cope with stress, and exhibit positive behaviors (Ibrahim, 2025; Ortner et al., 2025). Methods such as breathing exercises, mindfulness practices, and interaction with nature have been proven to be effective in reducing individuals' anxiety about environmental issues and encouraging environmentally friendly behaviors (Thomson and Roach, 2023; Curll et al., 2022). It is known that being in contact with nature increases environmental awareness and a sense of responsibility toward nature (Rakotomamonjy et al., 2014). Therefore, it is of great importance to promote strategies that strengthen the relationship between emotional regulation and eco-sensitivity.

Success in combating climate change requires a comprehensive awareness and action campaign that includes all segments of society. The coordinated action of public administration, civil society organizations, the private sector, and individuals, and the management of this process with a participatory governance approach, are of critical importance for the effectiveness of climate actions (Kulkov et al., 2024; Rykkja et al., 2014; Zhou et al., 2025). In Turkey, the strategies and action plans prepared by the Ministry of Environment, Urbanization, and Climate Change aim to increase social participation and reach broad audiences through education (ÇŞİDB, 2024).

In this study, the perspective of managing eco-anxiety and transforming it into behaviors that support environmental sustainability is placed at the center of efforts to strengthen climate literacy. The targeted study covers all demographic groups, from young people to the elderly, from farmers to city dwellers, and aims to develop awareness and proactive attitudes regarding climate change throughout society. Within this framework, emotional regulation techniques will be used to encourage individuals to adopt environmentally friendly behaviors, and effective psychological methods will be presented to reduce the negative effects of eco-anxiety during this process.

Climate Change, Eco-Anxiety, and Eco-Action

Climate change encompasses all deviations from the average state of the atmosphere that span decades. The IPCC Sixth Assessment Report emphasizes that, as of 2023, global warming has not only caused an increase in temperature but also shifts in precipitation patterns, rising sea levels, and an increase in both the frequency and intensity of extreme weather events (IPPC, 2023). This process is intertwined with the concepts of the greenhouse effect and global warming: the natural "blanket" composed of gases such as CO_2, CH_4, and N_2O regulates the Earth's energy balance by trapping long-wave radiation; however, human activities thicken this blanket, accelerating global warming. NASA's 2024 update details the physical and chemical basis of this mechanism (NASA Science, 2024).

The United Nations Framework Convention on Climate Change defines this phenomenon as "an anomaly in addition to natural variability resulting from changes in the atmospheric composition caused by human-induced emissions" (UNFCCC, 1992). Fossil fuel use, land-use changes, and industrial processes have driven global CO_2 emissions to a record high in 2024, raising atmospheric concentrations to 422 ppm (Friedlingstein et al., 2025). Current models show that this increase has heightened the risk of combined flooding in coastal cities (Long and Duan, 2025) and caused statistically significant shifts in global precipitation patterns (Tahroudi, 2025). Thus, anthropogenic greenhouse gas accumulation triggers global warming, which in turn fuels the multidimensional climate change process, deepening environmental and socio-economic risks at both global and local scales.

A Brief Overview of the Evolution of the International Climate Regime

Since the 1960s, the long-term risks of CO_2 increases in the atmosphere have become apparent in scientific literature, transforming the climate change debate into a global political agenda that transcends national borders. The 1972 Stockholm Conference first opened the discussion of environmental issues in international law; the 1979 Geneva World Climate Conference politicized the "greenhouse effect." The IPCC (1988), established in collaboration between UNEP and WMO, has institutionalized climate knowledge through regular assessment reports (Maslin et al., 2023).

The United Nations Framework Convention on Climate Change (UNFCCC), adopted in 1992, introduced the principle of "common but differentiated responsibilities." The Kyoto Protocol (1997) was the first binding protocol under this framework; however, its limited scope and enforcement weaknesses were subject to intense criticism in the literature of the time (Wiener and Felgenhauer, 2024).

The Bali Roadmap in the 2000s, the Copenhagen Accord (2009), and the Durban Platform (2011) accelerated the search for a comprehensive, universal, and flexible agreement. This search culminated in the 2015 Paris Agreement. The Paris regime:

1) aims to limit global temperature increase to "well below 2°C above pre-industrial levels, preferably 1.5°C,"

2) establishes National Determined Contributions (NDCs) that are updated every five years, and

3) the Enhanced Transparency Framework (ETF), which came into effect in 2024 (Kuramochi et al., 2024).

The most critical milestones post-Paris have been the Glasgow Climate Pact (COP 26, 2021) and the Dubai Decisions (COP 28, 2023). Glasgow produced a political signal with its statements on reducing methane emissions and a "phased exit" from coal; while Dubai identified the principles of a "fair, orderly, and equitable transition" from fossil fuels with a commitment to triple global renewable capacity and double energy efficiency by 2030 (Depledge et al., 2022).

Scientific documents have reinforced the urgency of these political frameworks. The IPCC's Sixth Assessment Synthesis Report (2023) reiterated the warning that "the 1.5°C threshold could be exceeded within a decade." UNEP's Emissions Gap Report 2024, meanwhile, states that current policies are leading to a 2.6°C pathway and that "the window for accelerating action is rapidly closing" (UNEP, 2024).

Turkey is classified as "highly vulnerable" to drought, coastal flooding, and extreme heat waves due to its location at the eastern end of the Mediterranean basin; IPCC AR6 reports that the duration and intensity of heat waves in the region have increased "with very high confidence" (Ali et al., 2022). Three heatwaves studied in Fethiye in 2019 significantly increased hospital admissions by 9–13% and deaths by a total of 22 excess deaths (Ozturk et al., 2023). The World Bank's 2023 Turkey CCDR summary emphasized that climate-related annual economic losses currently amount to around 1% of GDP and that inaction will rapidly increase this burden (World Bank Group, 2022).

On the policy front, Turkey ratified the Paris Agreement on October 7, 2021, through Law No. 7335. The updated National Contribution Statement presented in April 2023 formalized a 41% emission reduction by 2030 compared to the "business as usual" scenario and a net zero target by 2053 (UNFCCC, 2023). The realization of these commitments depends on strengthening water-energy-agriculture integration, gradually increasing carbon pricing, and expanding just transition financing.

The Effects of Climate Change

Although people are becoming increasingly aware of climate change, there is still a perception that the problem will be experienced "elsewhere and in the future" rather than "here and now." This perception, defined as "psychological distance" in social psychology literature, creates a false impression that the risk is not personal, thereby weakening the motivation to take action. A recent review shows that individuals who perceive the climate crisis as distant are both inconsistent in their risk assessment and reluctant to change their behavior (Newell, 2023).

The most concrete human outcome of a warming climate is an increase in extreme hot and cold weather events. Current data from the World Health Organization highlights the burden of a 1.6°C increase in global average temperature on cardiovascular and metabolic diseases, loss of productivity, and premature deaths. It also notes that cold weather attacks have intensified in some latitudes, particularly increasing mortality among vulnerable groups (WHO, 2024).

Fire seasons are now longer, and fires are more destructive. An analysis by the World Weather Attribution (WWA) focused on Los Angeles calculated that the 2024 fire disaster in the region would have been “statistically almost impossible” without human-induced warming. Similarly, a global study published in Nature Communications found that by 2025, the risk of an “extreme fire year” will have doubled in one-third of forest ecosystems (Abatzaoğlu et al., 2025).

Drought dynamics are also changing rapidly. A 2024 regional analysis of Turkey’s eastern regions reported a significant increase in both the number of dry days and agricultural stress over a 40-year series using the Standardized Precipitation Index. Similar assessments predict that “compound drought-temperature” events, which will negatively impact water-based energy production and food security, will intensify further over the next decade (Korkmaz et al., 2024).

Landslides, avalanches, and mudslides are also among the disasters sensitive to climate signals. A 2025 global modeling study shows that intensification of rainfall patterns could increase landslide susceptibility in high-altitude regions by up to 34% by mid-century. During the same period, field-based analyses have confirmed that irregular urbanization in urban-rural fringe areas further exacerbates risks (Capobianco et al., 2025).

Effects of Climate Change on Human Psychology

The impact of the climate crisis on mental health is now being addressed as a public health issue beyond environmental psychology, in light of current findings. The APA’s 2023 youth report shows that chronic stressors such as heat waves, drought, and air pollution permanently increase the risk of anxiety and depression in children and adolescents, and calls on professional organizations to promote “climate literacy.” Meta-analyses of extreme events show that the prevalence of post-traumatic stress disorder (PTSD) doubles after disasters such as hurricanes, floods, and mega-fires, and that repeated hurricane exposure in Florida exacerbates depression and anxiety, particularly among women. A recent systematic review reported that the incidence of PTSD, major depression, and generalized anxiety disorder remained “significantly elevated” in the five-year period following the 2024 Australian fires (Palinkas, 2024).

Indirect effects are equally striking. A global cross-sectional study documented that 59% of young adults experience “intense fear for the future” and that this fear reduces sleep quality; in a European multi-country cohort, climate anxiety was found to significantly increase the risk of insomnia and depression. A 2024 article in Nature emphasized that eco-anxiety has become the “dominant emotion” among young people, particularly in the Global South, causing them to postpone career, education, and family plans. A meta-analysis of rising average temperatures showed an OR of 1.24 for violent crime; urban homicide rates increased by 3.5% during periods of high temperatures. A 2024 review reported that each 1°C increase was associated with a 1.5% increase in suicide attempts. Finally, qualitative studies on the concept of "solastalgia" found that communities living in areas affected by mega-fires and rising sea levels experience identity loss and chronic grief through the experience of "in-place displacement." This body of evidence demonstrates that climate-based mental health risks span a wide spectrum, from acute trauma to chronic despair, and necessitate the integration of preventive mental health services into climate adaptation strategies (Runklea et al., 2025).

Transforming Eco-Anxiety into Eco-Action through Emotion Regulation

Flexible emotion regulation improves the quality of teaching and learning in educational settings and increases individual capacity for action in the fight against the climate crisis. A recent experimental study shows that the cognitive reappraisal strategy both strengthens teachers' well-being in the classroom and supports student participation; the same strategy also significantly increases the likelihood of pro-environmental behavior (Abbas and Iftikhar, 2025). The APA's 2023 report on children and youth emphasizes that climate-related stress triggers anxiety and sleep disorders, particularly in individuals under the age of 25, but that emotional regulation skills can buffer these effects (Clayton et al., 2023).

This psychological framework directly contributes to the two pillars of climate policy—mitigation and adaptation. According to IPCC AR6, renewable energy, energy efficiency, and the expansion of carbon sink ecosystems are priority tools for rapid and equitable emissions reductions; however, the continuation of public support depends on transforming climate anxiety from paralyzing to action-oriented emotions (IPPC, 2022). The same report highlights that locally tailored adaptation measures—climate-resilient infrastructure, drought-tolerant agriculture, social safety nets in disaster-prone areas—provide cost-effective protection for vulnerable communities. The UNDP's 2023/24 Human Development Report also notes that these strategies play a critical role in reducing climate injustice, particularly by raising indicators of "resilience" and "adaptive capacity" in low-income regions.

REFERENCES

Abatzoglou, J.T., Kolden, C.A., & Cullen, A.C. *et al.* Climate change has increased the odds of extreme regional forest fire years globally. *Nat Commun,* 16, 6390 https://doi.org/10.1038/s41467-025-61608-1

Abbas, M., Iftikhar, H. (2025). Face your feelings, save the planet: how we regulate emotions affects pro-environmental behavior. *Journal of Environmental Psychology*, 102687, https://doi.org/10.1016/j.jenvp.2025.102687.

Akbulut, M., & Kaya, A.A. (2021). Küresel iklim değişikliğinin psikolojik boyutu. *Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi*, *10*(3), 581-587.

Ali, E., Cramer, W., Carnicer, J., Georgopoulou, E., Hilmi, N.J.M., Le Cozannet, G., & Lionello, P. (2022). Cross-Chapter Paper 4: Mediterranean Region. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2233–2272, doi:10.1017/9781009325844.021.

Brophy, H., Olson, J., & Paul, P. (2023). Eco‐anxiety in youth: An integrative literature review. *International Journal of Mental Health Nursing*, *32*(3), 633-661.

Capobianco, V., Choi, C.E., Crosta, G., (2025). Effective landslide risk management in era of climate change, demographic change, and evolving societal priorities. *Landslides* 1, 1-19. https://doi.org/10.1007/s10346-024-02418-2

Chasek, P. (2022). The Legacies of the Stockholm Conference. *International Institute for Sustainable Development*, https://www.iisd.org/system/files/2022-05/still-one-earth-conference-legacy.pdf, Erişim Tarihi: 23.07.2025.

Clayton, S., Manning, C. M., Hill, A. N., & Speiser, M. (2023). *Mental Health and Our Changing Climate: Children and Youth Report 2023.* Washington, D.C.: American Psychol

Depledge, J., Saldivia, M., & Peñasco, C. (2022). Glass half full or glass half empty?: the 2021 Glasgow Climate Conference. *Climate Policy*, *22*(2), 147–157. https://doi.org/10.1080/14693062.2022.2038482.

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Landschützer, P., …, Zeng, J. (2025). Global Carbon Budget 2024, *Earth Syst. Sci. Data,* 17, 965–1039, https://doi.org/10.5194/essd-17-965-2025.

Ibrahim, M. (2025). Applying Emotional Regulation Strategies to Manage Climate. *Emotional Regulation-Theory and Application Across Clinical Settings: Theory and Application Across Clinical Settings*, 133.

IPCC (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

IPCC, (2022). Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-33, doi:10.1017/9781009325844.001.

Kankawale, S. M., & Niedzwiedz, C. L. (2023). Eco-anxiety among children and young people: systematic review of social, political, and geographical determinants. *MedRxiv*, 2023-12.

Korkmaz, M., & Kuriqi, A. (2024). Regional Climate Change and Drought Dynamics in Tunceli, Turkey: Insights from Drought Indices. *Water Conserv Sci Eng* **9**, 49, https://doi.org/10.1007/s41101-024-00281-9

Kulkov, I., Kulkova, J., Rohrbeck, R., Menvielle, L., Kaartemo, V., & Makkonen, H. (2024). Artificial intelligence-driven sustainable development: Examining organizational, technical, and processing approaches to achieving global goals. *Sustainable Development*, *32*(3), 2253-2267.

Kuramochi, T., Deneault, A., Chan, S., Smit, S., & Pelekh, N. (2024). Supporting the Paris Agreement through international cooperation: potential contributions, institutional robustness, and progress of Glasgow climate initiatives. *npj Clim. Action,* 3, 1-10. https://doi.org/10.1038/s44168-024-00106-4

Long, Z.Y., & Duan, H.F. (2025). Human mobility amplifies compound flood risks in coastal urban areas under climate change. *Communications Earth & Environment*, 6, 1-12. https://doi.org/10.1038/s43247-025-02406-x

Maslin, M. A., Lang, J., & Harvey, F. (2023). A short history of the successes and failures of the international climate change negotiations. UCL open. Environment, 5, e059. https://doi.org/10.14324/111.444/ucloe.000059.

Mersinlioğlu Serin, G. (2025). Birleşmiş Milletler iklim değişikliği konferansları ve sağlık: COP27, COP28 ve COP29'un genel bir değerlendirmesi. *Uluslararası Sağlık Yönetimi Ve Stratejileri Araştırma Dergisi,* 11(1), 1-12.

NASA Science (2024). What is the greenhouse effect?, https://science.nasa.gov/climate-change/faq/what-is-the-greenhouse-effect/?utm, Erişim Tarihi: 24.07.2025.

Newell, B.R. (2023). Strengthening psychological science for optimal climate communication and action policies. *One Earth*, 6, 341-342.

Ortner, C.N.M., Armstrong, M., Ulmer, E.J. (2025). Emotion regulation, climate distress, and climate action in climate activist and student samples. *Discover Psychology*, 5(15), 1-12. https://doi.org/10.1007/s44202-025-00338-3.

Ozturk, Y., Baltaci, H., & Akkoyunlu, B. O. (2023). The Impacts of Heat Waves on Hospital Admissions and Mortality in the Fethiye Province of Turkey. *Portuguese Journal of Public Health*, *41*(2), 94–101. https://doi.org/10.1159/000530747

Palinkas L. A. (2024). Long-term impacts of bush/wildfires on mental health: preparing for the next fire. *BJPsych open*, *10*(5), e153. https://doi.org/10.1192/bjo.2024.737

Rothschild, J., & Haase, E. (2023). Women's mental health and climate change part II: socioeconomic stresses of climate change and eco-anxiety for women and their children. *International Journal of Gynecology & Obstetrics*, *160*(2), 414-420.

Runklea, J.D., Herbsta, K., Ryanb, S., Sewella, S., Mallareb, A., Berryb, I., Getzb, E., McKeeb, A. Thompsonc, M.P., & Suggb, M.M. (2025). Eco-anxiety, climate concern, and fatalistic outlooks: Insights from U.S. crisis text conversations on climate distress. *The Journal of Climate Change and Health*, 22, 1-11. https://doi.org/10.1016/j.joclim.2025.100419 2667-2782.

Sezik, M., & Dokuyucu, E. (2025). İklim Değişikliği ve Türkiye'de Kentlerin İklim Değişikliği Politikalarına Uyum Sorunları. *Kent Akademisi*, *18*(1), 540-562.

Soltekin, O., Altındişli, A., & İşçi, B. (2021). İklim değişikliğinin Türkiye'de bağcılık üzerine etkileri. *Journal of Agriculture Faculty of Ege University*, *58*(3), 457-467.

Tahroudi, M.N. (2025). Comprehensive global assessment of precipitation trend and pattern variability considering their distribution dynamics. *Scientific Reports*, 15, 1-19. https://doi.org/10.1038/s41598-025-06050-5.

Türkeş, M. (2022). IPCC'nin Yeni Yayımlanan İklim Değişikliğinin Etkileri, Uyum ve Etkilenebilirlik Raporu Bize Neler Söylüyor?. *Resilience*, *6*(1), 197-207.

UNEP (2024). Emissions Gap Report 2024. https://doi.org/10.59117/20.500.11822/46404.

UNFCC (1992). *United Nations Framework Convention On Climate Change*, https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf?utm, Erişim Tarihi: 24.07.2025.

UNFCCC (2023). Republic of Türkiye Updated First Nationally Determined Contribution. https://unfccc.int/sites/default/files/NDC/2023-04/T%C3%9CRK%C4%B0YE_UPDATED%201st%20NDC_EN.pdf?utm, Erişim Tarihi: 23.07.2025

van den Berg, S., & Withers, A. (2025). Top UN court says treaties compel wealthy nations to curb global warming. https://www.reuters.com/sustainability/cop/top-un-court-says-treaties-compel-wealthy-nations-curb-global-warming-2025-07-23/, Erişim Tarihi: 23.07.2025.

WHO (2024). Heat and health. https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health?utm, Erişim Tarihi: 23.07.2025.

Wiener, J.B. & Felgenhauer, T. (2024). The Evolving International Climate Change Regime: Mitigation, Adaptation, Reflection. *Tex. A&M L. Rev.* 11(2), 451-485. https://doi.org/10.37419/LR.V11.I2.6.

World Bank Group (2022). Key highlights: Country climate and development report for Türkiye. https://www.worldbank.org/en/country/turkey/brief/key-highlights-country-climate-and-development-report-for-turkiye?utm, Erişim Tarihi: 23.07.2025

Zhou, T., Yang, D., Meng, H., Wan, M., Zhang, S., & Guo, R. (2025). A bibliometric review of climate change cascading effects: past focus and future prospects. *Environment, Development and Sustainability*, *27*(3), 5795-5820.

VIRTUAL REALITY (VR) AND AUGMENTED REALITY (AR) BASED MOTION LEARNING MODELS

Hediye YILDIRIM OGAN[1]

ABSTRACT

Recent advances in audio-visual technologies have transformed virtual reality (VR) and augmented reality (AR) environments into highly interactive laboratories for motor-skill training. VR's full-immersion capability shortens the sensorimotor feedback loop by instantly visualizing errors made during movement, whereas AR's integration with the physical world enables real-time adjustment of functional difficulty levels. Multicenter clinical trials and sport-pedagogy studies conducted in recent years show that adaptive tasks designed in VR/AR settings significantly enhance gross and fine motor skills, visuo-attention integration, and motivation. Nevertheless, long-term retention, optimization of multi-modal feedback, and low-cost hardware design remain under-explored. The present study discusses VR- and AR-based motor learning models within their theoretical foundations, empirical findings, and pedagogical design principles, highlighting critical research gaps and future directions.

INTRODUCTION

Motor learning arises from the interaction of multilayered cognitive-neuromotor mechanisms, such as interpreting sensory feedback, operating error-based correction processes, and adjusting task difficulty to individual competence. Traditional training and rehabilitation settings are not well suited to simultaneously track and optimize each of these mechanisms; fixed physical equipment does not allow real-time manipulation of task parameters (e.g., target size, speed, environmental complexity). At this juncture, VR and AR stand out for their software-driven capacity for dynamic intervention.

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The Challenge Point Framework (CPF) developed by Guadagnoli and Lee proposes that learning occurs within an "optimal cognitive load" zone determined by the interaction between the individual and the task (Thomas et al., 2025). Because VR and AR can alter difficulty parameters—such as target precision or environmental complexity—within milliseconds at the software layer, they provide a unique means of enacting CPF principles in real time.

Similarly, ecological dynamics theory ties the perception–action cycle to environmental constraints; fully immersive VR scenes or digitally integrated AR overlays offer unparalleled opportunities to experimentally manipulate those constraints. Finally, the embodied-cognition approach underscores that cognitive processes are inseparable from body movement and environmental context; this perspective furnishes a theoretical basis for integrating sensor data (IMU, EMG, skin conductance) with AI models to boost real-time adaptability in VR/AR environments (Mansour et al., 2025).

Global VR/AR market value reached USD 42.6 billion by the end of 2024, with education and healthcare being its fastest-growing subsectors. New-generation head-mounted displays (HMDs) provide 6-DoF tracking, wide fields of view, and higher resolutions, while haptic gloves and force-feedback exoskeletons broaden sensory integrity. Such hardware advances enable finely tuned feedback designs; for example, vibration cues synchronized with force graphs can intuitively convey error magnitude (Diller et al., 2025).

Systematic reviews published between 2019 and 2024 reveal that VR-based rehabilitation programs significantly improve gross motor skills (SMD ≈ 0.70) and upper-limb function in children with cerebral palsy. Likewise, AR-based adaptive target-manipulation studies (e.g., dynamically adjusting basketball-hoop diameter) demonstrate higher learning transfer than classical physical stimuli (Diller et al., 2025). Nonetheless, 62 % of the current literature focuses on short-term interventions (≤ 4 weeks), employs limited sample sizes, and treats motivational variables such as flow as secondary outcomes (Hader et al., 2025).

Key unresolved issues include:

- **Long-term retention:** Few studies report follow-up measurements beyond 12 weeks.
- **Multi-modal feedback optimization:** The interplay of visual, auditory, and haptic cues has yet to be systematically analyzed.
- **Accessible hardware:** Delivering low-cost, scalable solutions to clinical and educational settings remains challenging.

AUGMENTED REALITY-BASED MODELS

Functional Difficulty Optimization

Turakhia et al. developed an AR system on HoloLens 2 that dynamically alters virtual-hoop diameter according to user performance. The adaptive version achieved a 15 % higher hit rate than the fixed version, underscoring that visual alignment and depth perception are critical when applying CPF to AR contexts (Turakhia et al., 2025).

Sensory-Cue-Based Interventions

The Strolll software superimposes flowing colored lines on the floor via AR, reducing freezing episodes in Parkinson's patients by 40 % and doubling weekly exercise duration. External-cue strategies appear particularly effective for stabilizing gait rhythm and triggering automatic motor circuits (Diller et al., 2025).

2.3 Gamification and Field-Based Training

The SkillAR platform uses point-based scoring and a level system in field-based bicycle-balance training, increasing participation time by 28 %. However, the long-term motivational effects of gamification components remain unclear due to small sample sizes (Diller et al., 2025).

DESIGN CHALLENGES

- **Depth Illusion:** Misalignment of virtual objects with the physical world can disrupt target-movement calibration.
- **Visual Clutter:** Elevated screen load may increase cognitive load, particularly in older populations.
- **Hardware Ergonomics:** Headset weight and battery life limit continuity in field applications.

CONCLUSION

VR and AR-based motor-learning models offer innovative and effective approaches in education. VR provides a safe, immersive environment for developing physical skills, whereas AR merges virtual elements with the real world to deliver practical, interactive learning experiences. Both technologies enrich motor-learning processes, helping learners develop skills more rapidly and effectively. Studies in sport, rehabilitation, and vocational training clearly demonstrate their potential.

However, several barriers must be overcome for widespread adoption, including high costs, technical limitations, and physical discomfort. With ongoing technological advances and decreasing costs, VR and AR are expected to play a more prominent role in educational systems. Integration with artificial-intelligence and machine-learning technologies can further enhance their effectiveness by allowing greater personalization of learning processes.

In sum, VR and AR-based motor-learning models hold transformational potential in education, making learning more interactive, effective, and accessible, and thereby contributing significantly to the education of future generations.

REFERENCES

Bagir, M., Önal Karakoyun, G., & Asiltürk, E., (2022). Views of Science Teachers on the Use of Artificial Intelligence in Education. *İnternational Online Journal Of Educational Sciences* , vol.14, no.5, 1223-1234.

Çelik, R., Önal Karakoyun, G., & Asiltürk, E., (2022). Evaluation of Middle School 7th Grade Science Skill-Based Questions According to the Revised Bloom Taxonomy. *İnternational Online Journal Of Educational Sciences* , vol.14, no.3, 705-716.

Diller, F., Henkel, N., Scheuermann, G. *et al.* SkillAR: omnipresent in-situ feedback for motor skill training using AR. *Virtual Reality* **29**, 33 (2025). https://doi.org/10.1007/s10055-025-01108-1

Erbek, N., Asiltürk, E., & Kahyaoğlu, M. (2023). Fen Bilimleri Öğretmenlerinin İnovatif Düşünme Becerilerine İlişkin Özyeterlilik Algılarının Çeşitli Değişkenler Açısından İncelenmesi. Fen Bilimleri Öğretimi Dergisi, 11(1), 153-179. https://doi.org/10.56423/fbod.1264434

Hajder, Đ., Bjelica, B., Bubanj, S., Aksović, N., Marković, M., Arsenijević, R., Lupu, G. S., Gašić, T., Sufaru, C., Toskić, L., Dobreci, D. L., Dobrescu, T., & Sava, M. A. (2025). A Systematic Review and Meta-Analysis of Virtual and Traditional Physical Activity Programs: Effects on Physical, Health, and Cognitive Outcomes. *Healthcare (Basel, Switzerland)*, *13*(7), 711. https://doi.org/10.3390/healthcare13070711

Lehrman, A. L. (2025). Embodied Learning Through Immersive Virtual Reality: Theoretical Perspectives for Art and Design Education. *Behavioral Sciences*, *15*(7), 917. https://doi.org/10.3390/bs15070917

Mansour, N., Aras, C., Staarman, J.K. *et al.* Embodied learning of science concepts through augmented reality technology. *Educ Inf Technol* **30**, 8245–8275 (2025). https://doi.org/10.1007/s10639-024-13120-0

Önal Karakoyun, G. & Asiltürk, E. (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure- Acidity/Basicity Relationship" Topic. *Acta chimica Slovenica*, *68*(3), 645–657.

Önal Karakoyun, G., & Asiltürk, E., (2020). Analysis of Pre-Service Science Teachers' Heuristic Reasoning Processes about Hydrogen Bonding. Journal of Science Learning, vol.4, no.1, 50-60.

Thomas, A., Paul, L., Rasenyalo, S., Jones, B., & Hendricks, S. (2025). Challenge Accepted: A Systematic Scoping Review of the Applications of the Challenge Point Framework. *Journal of Motor Behavior*, *57*(4), 444–462. https://doi.org/10.1080/00222895.2025.2508283

Turakhia, D., Parent, M., Grossman, T., Glueck, M., & Lafreniere, B. (2025). Investigating Augmented Reality for Adaptive Motor-Skill Training. *In Proceedings of Graphics Interface* (GI '25). ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

Uğraş, M., & Çil, E. (2016). Determination of views of pre-school teachers on scientific process skills and level-of-effort on basic scientific process skills use in science activities. The Eurasia Proceedings of Educational and Social Sciences, 4, 357-362.

INTEGRATING E SPORTS INTO THE PHYSICAL EDUCATION CURRICULUM

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ABSTRACT

E-sports—organised, competitive video-gaming that emulates the institutional logics of traditional sport—has emerged as a powerful cultural force that intersects schooling, youth culture, and the digital economy. Global audiences surpassed 650 million in 2025 (Newzoo, 2025), and more than one-third of K-12 schools worldwide now host official e-sports programmes (REN Network, 2025). Beyond entertainment value, structured game play fosters decision-making, spatial reasoning, and teamwork, while new scholarship demonstrates links to career readiness in science, technology, engineering, and mathematics (STEM) fields. This chapter interrogates the pedagogical, health-related, and ethical implications of embedding e-sports within the Physical Education (PE) curriculum. Drawing on a systematic mapping of peer-reviewed literature, policy reports, and institutional case studies published between 2017 and 2025, we propose evidence-based integration models and multidimensional assessment frameworks. The aim is to equip PE teachers, curriculum designers, and policy-makers with a scientifically grounded, inclusive, and practicable roadmap.

INTRODUCTION

Members of Generations Z and Alpha, often labelled “digital natives,” blend physical and virtual experiences into hybrid lifestyles. Conventional PE programmes—which historically privilege gross-motor skill acquisition, fitness goals, and team sportsmanship—face mounting pressure to incorporate digital competencies and twenty-first-century skills (Jenny et al., 2017). Digital technologies are widely used in science (Bagır ve ark., 2022; Bulduk, 2024;

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Çelik et all., 2022; Çetinkaya, 2017; Erbek et all., 2023; Önal Karakoyun et all., 2025; Önal Karakoyun & Asiltürk, 2022; Önal Karakoyun & Asiltürk, 2021) and mathematics (Baldemir ve Tutak, 2024; Cırık ve Akpolat, 2024; Güneş, 2022; Nayıroğlu ve Tutak, 2024; Polat ve Tutak, 2025; Süzen ve ark., 2024) education today. E-sports offers a novel avenue for achieving these objectives by uniting strategic cognition, problem-solving, and digital citizenship with the motivational affordances of competitive play. However, screen-time management, sedentary risk, and incidents of cyberbullying present significant challenges. This chapter systematically reviews extant research and organises discussion around four thematic pillars:

(1) Pedagogical potential;

(2) Curriculum integration strategies;

(3) Health, well-being, and ethics;

(4) Assessment and evaluation approaches.

PEDAGOGICAL POTENTIAL: COGNITIVE, SOCIAL, AND EMOTIONAL DIMENSIONS

E-sports participation cultivates fast, context-sensitive decision-making, sustained selective attention, and predictive problem-solving—skills that align with contemporary PE learning outcomes (Jenny et al., 2017). A 2024 systematic review of competitive gaming in educational contexts found that team-based titles, such as Rocket League and League of Legends, significantly enhanced students' collaborative communication and critical-thinking scores compared with control cohorts (Devi Puspitasari & Santosa, 2024). In secondary schools, involvement in e-sports clubs correlated with measurable reductions in bullying and heightened sense of belonging. These findings resonate with social-emotional learning (SEL) theories, particularly the "communities of purpose" construct, positing that shared objectives promote pro-social behaviour. Nevertheless, online harassment disproportionately targets female and LGBTQ+ gamers, necessitating robust inclusion policies and active moderation protocols (Jenny et al., 2017).

CURRICULUM INTEGRATION STRATEGIES: COURSE DESIGN AND LEARNING OUTCOMES

State-Approved Secondary Electives

The Texas State Board of Education approved the innovative elective "Gaming Concepts Fundamentals" for the 2024-2025 school year, conferring PE credit equivalence (Munroe Chandler et al., 2023). The standards encompass game history, strategic analysis, ergonomics, and wellness practices. Students monitor heart-rate data via wearables during practice sessions and conclude the course by constructing STEM career maps.

Multi-Layered Higher-Education Models EdTech

Magazine highlights tripartite higher-education frameworks in which e-sports is embedded across “competition,” “community,” and “curriculum” axes (Radmann, & Midthaugen, 2024). NorthWest Arkansas Community College, for example, designates e-sports as a secondary athletic stream to expand access while limiting travel expenditures (Formosa et al. 2022). Definitions of esports: a systematic review and thematic analysis. *Proceedings of the ACM on Human-Computer Interaction*, *6*(CHI PLAY), 1-45.). Interdisciplinary modules encompass game-mechanics analytics, data science, and broadcast production. An Issues in Information Systems case study revealed positive revenue generation, scholarship opportunities, and graduate employability outcomes associated with such programmes (Rerick & Moritz, 2023).

HEALTH, WELL-BEING, AND ETHICAL DIMENSIONS

Physical Activity and Ergonomics

Extended screen exposure elevates risk for musculoskeletal disorders. PE educators should embed 15-minute active-break blocks into practice schedules and enforce the 20-20-20 ocular health guideline (look 20 feet away for 20 seconds every 20 minutes). The aforementioned Gaming Concepts curriculum mandates complementary cardiovascular training grounded in established sport-science principles (Radmann & Midthaugen, 2024).

Digital Well-being and Parental Perceptions

A 2025 Parents.com survey reported a substantial decline in negative parental attitudes towards gaming, attributed to perceived benefits in strategic thinking, teamwork, scholarships, and career trajectories (Munroe Chandler et al., 2023). Ethical implementation requires age-rating adherence, anti-bullying interventions, data-privacy safeguards, and codified fair-play protocols.

ASSESSMENT AND EVALUATION APPROACHES

In-Game Analytics Coupled with Traditional PE Metrics

Modern e-sports platforms generate granular telemetry—actions per minute (APM), reaction-time indices, decision counts—that can be triangulated with conventional PE assessments such as VO2 max estimates and agility drills. A 2024 GESS Education report documented an 18 per cent rise in weekly physical-activity minutes among students enrolled in school e-sports leagues (Formosa et al. 2022).

Twenty-First-Century Skills and SEL Rubrics

Collaborative problem-solving, leadership, and self-regulation can be evaluated via rubric-based analysis of match replays informed by analytic dashboards. Reflective journals encourage metacognitive awareness, aligning with SEL frameworks (Kim et al., 2021).

CONCLUSION

Integrating e-sports into the PE curriculum offers a strategic response to the pedagogical imperatives of the digital era. Empirical evidence underscores benefits in cognitive flexibility, social inclusion, and career motivation, provided that health and ethical risks are mitigated through structured safeguards. Implementation guidelines include: (1) phased adoption plans; (2) compulsory physical-activity modules; (3) embedded cyber-safety and digital-citizenship instruction; and (4) multimodal assessment regimes. Future research should explore longitudinal health outcomes and culturally responsive adaptations.

REFERENCES

Bagir, M., Önal Karakoyun, G., & Asiltürk, E., (2022). Views of Science Teachers on the Use of Artificial Intelligence in Education. *İnternational Online Journal Of Educational Sciences, vol.*14, no.5, 1223-1234.

Baldemir, B., & Tutak, T. (2024). Okul Öncesi Öğretmenlerinin Diskalkuliye Yönelik Farkındalık Düzeylerinin Belirlenmesi. *Cumhuriyet Uluslararası Eğitim Dergisi,* 13(4), 847-857. https://doi.org/10.30703/cije.1371417

Bulduk, Ö. (2024). Fen bilimleri konu öğretimi ve öğrenimi ile ilgili öğretmen ve öğrenci ihtiyaçlarının belirlenmesi: Bir devlet ortaokulu örneği. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi*, 59, 205-239.

Cırık, İ., & Akpolat, T. S. (2024). Abdüktif düşünmenin k12 beceri geliştirme sürecindeki rolü: Matematik dersi Örneği. *Milli Eğitim Dergisi*, *53*(241), 519-542.

Çelik, R., Önal Karakoyun, G., & Asiltürk, E. (2022). Evaluation of middle school 7th grade science skill-based questions according to the revised bloom taxonomy. *International Online Journal Of Educational Sciences* , 14(3), 705-716.

Çetinkaya, M. (2017). Fen eğitiminde modelleme temelinde düzenlenen kişiselleştirilmiş harmanlanmış öğrenme ortamlarının başarıya etkisi. *Ordu Üniversitesi Sosyal Bilimler Araştırmaları Dergisi*, 7(2), 287-296.

Devi Puspitasari, N.L.P., & Santosa, M.H. (2024). E-Sport in Education: A Systematic Review of Enhancing EFL Learning through Competitive Gaming Activity. *JED: Journal of English Development*, 4(2), 511-522. https://doi.org/10.25217/jed.v3i01.4811

Erbek, N., Asiltürk, E., & Kahyaoğlu, M. (2023). Fen Bilimleri Öğretmenlerinin İnovatif Düşünme Becerilerine İlişkin Özyeterlilik Algılarının Çeşitli Değişkenler Açısından İncelenmesi. Fen Bilimleri Öğretimi Dergisi, 11(1), 153-179. https://doi.org/10.56423/fbod.1264434

Formosa, J., O'donnell, N., Horton, E. M., Türkay, S., Mandryk, R. L., Hawks, M., & Johnson, D. (2022). Definitions of esports: a systematic review and thematic analysis. *Proceedings of the ACM on Human-Computer Interaction*, *6*(CHI PLAY), 1-45.

Güneş, F. (2022). The direct instruction model. *The Journal of Limitless Education and Research*, *7*(1), 1-39.

Jenny, S. E., Manning, R. D., Keiper, M. C., & Olrich, T. W. (2017). Virtual(ly) athletes: Where esports fit within the definition of sport. *Quest*, 69(1), 1-18.

Kim, S. J., Kim, S. Y., & Lee, G. (2021). Learning from eSports: A review, comparison, and research agenda. *Pan-Pacific Journal of Business Research*, *12*(1), 61-80.

Munroe-Chandler, K. J., Loughead, T. M., Zuluev, E. G., & Ely, F. O. (2023). An imagery-based intervention for managing anxiety in esports. *Journal of Imagery Research in Sport and Physical Activity*, *18*(s1), 20230005.

Nayıroğlu, B., & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Educational Studies*, 11, 65-78. https://doi.org/10.33907/turkjes.1415591

Önal Karakoyun, G. & Asiltürk, E. (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure- Acidity/Basicity Relationship" Topic. *Acta chimica Slovenica*, *68*(3), 645–657.

Önal Karakoyun, G., & Asiltürk, E., (2020). Analysis of Pre-Service Science Teachers' Heuristic Reasoning Processes about Hydrogen Bonding. Journal of Science Learning, vol.4, no.1, 50-60.

Polat, M., & Tutak, T. (2025). Interdisciplinary comparative analysis of science and mathematics teachers' level of technology use in teaching processes, their aims and problems encountered. *International Journal of Research in Teacher Education (IJRTE)*, 16, 34-48. https://doi.org/10.29329/ijrte.2025.1300.03

Radmann, A., & Midthaugen, P. (2024). Esports in Norwegian Upper Secondary Education: Integration, Challenges, and Opportunities in the 21st Century. *Critical perspectives on esports*, 135-151.

Rerick, M. A., & Moritz, S. E. (2023). Coaches as teachers and facilitators of esports imagery use. *Journal of Imagery Research in Sport and Physical Activity*, *18*(s1), 20230013.

Süzen, A. B., Tutak, T., İlhan, A., Nayıroğlu, B. (2024). Teacher and Student Opinions on Teaching Four Operations with Integer Numbers in 7th Grade with Counting Stamps. International E-Journal of Educational Studies, 8(17), 142-156. https://doi.org/10.31458/iejes.1343835

BLENDED LEARNING MODEL AND THE FLIP CLASSROOM MODEL, WHICH IS A BLENDED LEARNING MODEL

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Abstract

In the developing and changing world, technology has affected every aspect of life as well as education. New learning models have been developed with the introduction of learning environments that emerged with technology into education. One of these is the blended learning model, which emerged by combining online learning environments with face-to-face learning models. In this study, the blended learning model is introduced and the benefits and types of blended learning are briefly mentioned. In addition, the definition of the flipped classroom model, which is a blended learning model, is made, its components are explained and its benefits are mentioned.

Keywords: Blended learning, flipped classroom model, learning models

Introduction

Education is the process of providing individuals with desired behaviors as a result of their experiences. In the changing and developing world, changes have occurred in many aspects of life. The most important of these is the use of developing technology in education and the introduction of new education and training strategies into our lives (Ünsal, 2018). In classes where students with different learning levels are together, monotonous traditional education causes students to get bored and permanent learning does not occur. Especially when considering today's student profile, called Generation Z, which has grown up intertwined with technology, the methods used in education need to be developed and supported with technology (Serçemeli, 2016).

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In this context, developed and developing countries continue to renew and develop their educational programs in order to meet the requirements of the age in their educational systems (İşman, 2011). Since more time is allocated to the theoretical part of the course in the traditional education model, there is a time problem especially in the mathematics course where problem solving skills and operational skills are tried to be acquired. This time problem can be overcome by supporting education with technology (Kaya, 2018). With the flipped classroom model, the theoretical information of the course should be acquired by the student with the help of technology at home, and application and skill acquisition are carried out by the teacher at school. Thus, the student moves from the listener role in the traditional education model to the implementer role, and the teacher moves from the narrator role in the traditional education model to the guide role. While traditional learning takes place face to face, in the flipped classroom model, education takes place face to face, virtual and blended. Bishop and Verleger (2013) define the flipped classroom model as a pedagogical model in which students use active learning skills in the classroom. In other words, when the flipped classroom model and the traditional method are considered, it is seen that in these two methods, in-class and out-of-class practices are replaced, and especially the applied parts are carried out interactively in the classroom. In-class teaching is designed for students to practice at an advanced level, and thus it is aimed for them to take an active part in the education process (Öztürk, Karademir, Yılmaz & Yılmaz, 2015).

The flipped classroom model was first defined and implemented as doing lessons at home and homework at school (Lage et al., 2000; Talbert, 2012; Tucker, 2012). Later, the flipped classroom model was seen that students mostly carried out activity and problem-solving-based activities in a collaborative manner rather than homework in class (Bishop and Verleger, 2013). Thus, it is generally seen that it is defined as a model in which students learn course content individually and at their own pace with pre-prepared videos, and in the classroom, they work with high-level activities with their peers and under the guidance of their teachers (Bergmann and Sams, 2012; Hoffman, 2014; Talbert, 2012; Tucker, 2012).

An important benefit of the flipped classroom model has been stated in many studies as increasing the time teachers spend on in-class activities (Ingram et al., 2014; O'Flaherty and Phillips, 2015; Tekin and Emmioğlu-Sarıkaya, 2020; Tucker, 2012). Other benefits include teachers having more opportunities to use methods such as active learning, collaborative learning, problem solving or peer learning in their classes, and students taking responsibility for their own learning, making classroom management easier for the teacher (Bergmann and Sams, 2012).

Technology both directs education and feeds off of it in order to advance humanity and make life easier. Education is not only intertwined with technology, but also directs technology. While this situation shows us that education and technology should not be separated from each other, it is also an undeniable fact that an education without the use of technology will leave us behind the times (Bayır, 2024).

With the integration of technology into education, the concept of blended learning emerges. Blended learning is formed by using distance online learning and traditional education models together. Eastman (2015) mentions the blended learning model as a teaching strategy that combines face-to-face education with individualized, student-directed, computer-based learning programs (Çınar and Ünsal, 2024). With technology, differentiation can be made in the education of students with different learning levels. Education becomes individualized with blended learning. Each student gains individual education opportunities in an online learning environment with the blended education model based on their own knowledge and taking their learning level into consideration. In school, students can gain skills that they could not acquire when only the traditional education model was applied by practicing with the blended education model.

The roles of the teacher and student have also changed with the blended learning model. While the teacher is a narrator who only transfers theoretical knowledge in the traditional learning model, he is in the role of a guide in the blended learning model. The student, on the other hand, moves from the listener and understander role in the traditional learning model to the interpreter and implementer role with the blended learning model.

Benefits of Blended Learning

The blended learning model is an approach that enriches and diversifies learning opportunities by combining traditional classroom education methods with online learning technologies, thus providing students with flexibility suitable for different learning styles and needs (Bayır, 2024). With this flexibility, the first leg of blended learning, which is distance learning where theoretical knowledge is acquired, is acquired, and students can complete their education at their own pace and according to their own needs by saving time and space. Thus, students who acquire theoretical knowledge can express themselves better in face-to-face classroom practices and play an active role. In addition, since a more interactive environment is created compared to traditional education practices while classroom practices are carried out in the blended education model, it is possible to correct mistakes or misconceptions that have been made. Since students interact with each other in blended learning classroom practices, peer teaching can be provided. With peer teaching, individuals learn that they can defend their own ideas and be open to different ideas.

As a result, the blended learning approach creates opportunities for individual learning, individual speed, diversity in terms of listening, reading, seeing and application, cooperation and communication diversity. It can also be stated that it creates positive effects such as speed in feedback, freedom in the learning environment, increasing learning motivation, and saving time and learning costs (Ünsal, 2010).

Types of Blended Learning

The blended learning model is a learning model that emerges by using the face-to-face education model and the distance education model together. Blended learning types are divided into four as flexible learning model, individual blended learning model, rotation learning model, and enriched learning model. The rotation learning model is divided into flipped classroom model, station rotation model, laboratory rotation model, and individual rotation model (Bayır, 2024). Blended learning types are shown in Table 1 below.

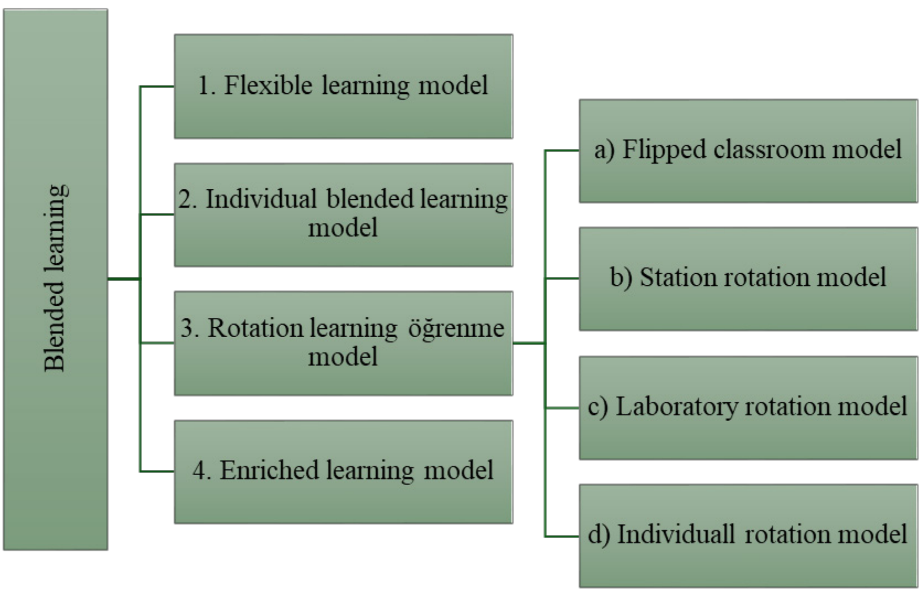

Table 1. Types of blended learning (Horn and Staker, 2017)

Blended learning types are shown in Table 1 above. If we look at the table made by Horn and Staker (2017); The first steps of blended learning are Flexible learning, Individual blended learning model, Rotation learning model and

Enriched learning model. These are followed by the steps of Flipped classroom model, Station model, Laboratory model and Individual rotation model.

Face-to-face learning model:

• It is the most suitable model in terms of application in the school learning environment.

• It allows the number of students participating to be a certain number.

• While students work on topics that they think are above their level and difficult, they can improve their own learning speed with the support of technology (Taşkın and Aksoy, 2023).

Distance learning model:

• It has the opposite learning characteristics from the face-to-face learning model.

• Teaching materials are presented to students in online environments.

• Participation in face-to-face learning is left to the students' own preferences.

• Students ask their questions about the course in online environments.

• The distance learning model attracts students' attention because the daily lesson plan can be flexible and independent (Taşkın and Aksoy, 2023).

1. Flexible learning model:

• In this learning model, course materials are presented to students in online environments.

• Learning first occurs with the student's own guidance and self-organization.

• Learning is created according to the students' own interests and needs.

• It is possible to switch between learning models (Taşkın and Aksoy, 2023).

2. Individual blended learning model:

• It provides students with the opportunity to learn outside of what is given at school.

• In this model, lessons can be given face-to-face in the school environment and supported in online environments.

• In order to get efficiency from the education provided with this model, students' interest and motivation must be high (Taşkın and Aksoy, 2023).

3. Rotation learning model:

• In this learning model, students work alternately between learning models (face-to-face and online) within the framework of a specific program.

• It is seen that this model is mainly used in primary schools (Taşkın and Aksoy, 2023).

a) Flipped classroom model:

• It is formed by reversing the time spent on learning in the traditional education model and transferring it to applications.

• It supports individual learning by ensuring that students are responsible for their own learning.

• It allows the teacher to support each student in line with their wishes and needs with his/her guiding role.

• It allows students to plan their learning according to their own pace (Taşkın and Aksoy, 2023).

b) Station rotation model:

• There is a time limit in the lesson or subject.

• Students work in different online learning environments.

• Group project assignments, paper-and-pencil assignments can be done in the stations prepared in online learning environments (Taşkın and Aksoy, 2023).

c) Laboratory rotation model:

• It is implemented to help students complete their courses.

• Students complete their studies in online learning environments.

• Students can use computer laboratories to complete their studies related to their courses.

• A guide is there to support students while they continue their studies in the laboratories (Taşkın and Aksoy, 2023).

d) Individual rotation model:

• In this learning model, students continue their studies on certain stations that have been prepared in advance.

• In this learning model, each student can individualize their own learning by taking advantage of online learning activities according to their own needs (Çınar and Ünsal, 2024).

4. Enriched learning model:

• In this learning model, students can complete their education by benefiting from face-to-face learning in the classroom and at the same time benefiting from the richness brought by online learning environments (Çınar and Ünsal, 2024).

Flipped Classroom Model

The flipped classroom model is a subheading of the blended learning model and is a learning model that combines online learning with in-class activities (Staker & Horn, 2012). The flipped classroom model is also encountered in the peer teaching strategy put forward by Mazur (1997), where students study courses topics at home and do their homework in class (Mazur, 1997). The concept of the flipped classroom model was expressed by Baker in an international conference held in Florida in 2000 (Temizyürek and Ünlü, 2015).

Jonathan Bergman and Aaron Sams, who taught in the United States in 2007, stated that students need their teachers more when they are doing their homework at home, that is, when they are doing the practical part of their lessons, than when they are learning the theoretical knowledge of the lesson in class. For this reason, they recorded their lessons and shared them with their students in online teaching environments in order not to waste time by explaining the points that were not understood over and over again for students who missed the lesson. In this way, they continued their lessons in a more interactive way with their students in the practical part of the lesson during them in-class time and provided opportunities for students to express themselves by including in-class discussions on the points that they did not understand (Bergman and Sams, 2012).

The flipped classroom model is generally defined as the exact opposite of the traditional education model where the theoretical part of the course is done at school and the practical part is done at home as homework. In other words, the learner should program their learning at home according to their own learning pace and support their learning in a practical way with the guidance of their teacher in the classroom.

In a learning model where the flipped classroom model is used, the teacher prepares presentations, learning materials, videos, educational games, and quizzes related to the subject to be published in online environments before the lesson. The student must program and complete these learning activities prepared by the teacher based on his/her own speed and skills. Since these learning activities depend on the student, learning becomes more permanent and impressive as the student can repeat the parts he/she does not understand until he/she understands them. Thus, learning takes place by focusing on the individual (Çınar and Ünsal, 2024).

In the classroom, students who complete their learning at their own pace and participate in the application can express themselves more comfortably in in-class discussions. In class activities, peer learning is enabled when students are given the opportunity to discuss the subject with each other. In this way, students are provided with the ability to express themselves and respect other ideas. By acting as a guide in in-class activities, the teacher can help students in their problem-solving processes and provide them with problem-solving skills.

Components of the Flipped Classroom Model

The flipped classroom model is defined worldwide as the "Flipped Classroom". Some components have been presented to make this teaching model easier to explain. These components consist of the letters "F-L-I-P" in the name of the model. The letter F stands for Flexible Environment, the letter L for Learning Culture, the letter I for Intentional Content, and the letter P for Professional Educator (Flipped Learning Network, 2014; Çenberci, Karakulak, & Tol, 2023).

The components of the flipped classroom model can be divided into two as in-class and out-of-class components. Presentations where the theoretical information of the course is conveyed, various videos; various learning management systems where lecture notes are shared and guidance is provided, and short online assessment exams constitute the out-of-class components of the flipped classroom model. The in-class components of the flipped classroom model consist of problem-solving-based learning and various group activities (Temizyürek and Ünlü, 2015).

Basic Elements of Flipped Learning Environments

In order for learning to take place fully in learning environments where the flipped classroom model is applied, learning should be programmed in a way that is compatible and interactive with collaboration, individual-centered learning, the most ideal learning environment, sufficient time for in-class practices, guide support, technology support, feedback and evaluation elements.

• Collaboration: It is seen that learning environments with effective communication and collaboration make learning permanent.

• Individual-centered learning: Individualized learning is seen in learning where the teacher is in the role of a guide and the student is in the role of an implementer.

• The most ideal learning environment: The classroom layout should be organized in a way that allows students to work individually or in groups.

• Sufficient time for in-class applications: Sufficient time should be provided for applied learning environments and the teacher should schedule the learning material that he/she will apply in advance in terms of time.

• Guide support: School administrators should guide and guide teachers.

• Technology support: Teachers should receive support from people who are experts in technology when organizing online learning environments.

• Feedback and evaluation: Teachers should organize learning environments to make them the best with feedback and evaluations (Ünsal, 2018).

Implementation of the Flipped Classroom Model

Today's students, born in the age of technology, need learning environments that require them to adapt the information they learn in collaboration with other students to different situations and use developing technology in their learning. It is clearly seen that traditional learning environments are inadequate in providing these opportunities. The flipped classroom model emerges at the point of providing these opportunities (Çenberci, Karakulak, & Tol, 2023).

The flipped classroom model stands out in terms of providing permanent learning, providing effective learning experiences, flexible study time, providing easy access to learning anytime and anywhere, saving time and space, and offering individualized learning (Bozdağ and Gökler, 2023). The flipped classroom model, which offers students a personalized learning experience, does not limit learning to face-to-face learning models. With online education environments, students program their learning according to their own learning needs, at their own pace, at their own place and time. In this way, students take responsibility for their own learning (Davies, Dean, and Ball, 2013).

In the study conducted by Bulut and Bekdemir (2024), it was observed that in the classroom where the flipped classroom model was applied, the teaching was programmed cyclically in such a way that the order of presentation of online work outside the classroom to the students, students performing online work on EBA, the teacher preparing in-class learning materials by examining the work done by the students on EBA, presentation of in-class learning materials to the students, the teacher reporting the learning activities and evaluating them with the expert was maintained (Bulut and Bekdemir, 2024).

Benefits of the Flipped Classroom Learning Model

When various studies on the flipped classroom model are examined, the flipped classroom model generally attracts the attention of students. The flipped classroom model supports students' learning by offering them individualized learning. The flipped classroom model allows students to gain learning skills by increasing the time allocated to the application of the course. Thus, in the studies conducted, it is observed that the flipped classroom model reduces students' learning anxiety towards the course, develops a positive perspective towards the course, and ensures permanent learning.

Students stated that they did not have any difficulty in classroom and out-of-class applications in learning environments where the flipped classroom model was applied, that they found these applications enjoyable and interesting, that this learning model facilitated learning and provided permanent learning, thus they had positive views (Çenberci, Karakulak, & Tol, 2023). In the study conducted by Çınar and Ünsal (2024), it was stated that the flipped classroom model created positive views in terms of motivation and success in teaching mathematics (Çınar & Ünsal, 2024).

It can be said that the flipped classroom model positively affects academic success because it is suitable for interaction and application, and because it individualizes learning and provides active learning. In addition, it can be stated that thanks to the flipped classroom model used in mathematics education, there is an increase in students' participation in mathematics lessons and their use of technology (Ezantaş and Karakaş, 2021). Online learning environments and various materials prepared in the flipped classroom model increase students' learning before in-class lessons, allowing them to come to classes prepared and actively participate in in-class practices (Bozdağ and Gökler, 2023).

When the in-class effects of the flipped classroom model were examined, it was stated that students followed the lesson more comfortably because their readiness was high in the light of the information they acquired in the online learning environment. Thus, students will have the opportunity to reinforce their learning more (Çenberci, Karakulak, & Tol, 2023).

In these contexts, the flipped classroom model;

• It can be said that it increases students' motivation (Bulut and Bekdemir, 2024),

• It makes learning fun (Ünlütürk and Bakioğlu, 2023),

• It allows learning by doing and experiencing (Ünlütürk and Bakioğlu, 2023),

• It creates permanent learning (Turan and Göktaş, 2015),

• It saves time and space with technology support (Çınar and Ünsal, 2024),

• It individualizes learning (Ünsal, 2018),

• It allows students to play an active role in learning (Ünsal, 2018),

• It saves time for practice in classroom activities (Çenberci, Karakulak and Tol, 2023),

• It contributes to the formation of a student-centered learning environment (Ünsal, 2018).

Suggestion

Blended learning is a learning model that offers the opportunity to individualize learning according to the needs and pace of the student with the support of technology. The blended learning model is formed by blending the face-to-face learning model and the online learning model. The flipped classroom model is the opposite of the traditional learning model. In the traditional learning model, the theoretical part of the course is programmed to be face-to-face and the practical part to be at home. In the flipped classroom model, this situation is the opposite. The student learns at home by programming the theoretical part of the course at his own pace and the opportunity to repeat the parts he does not understand, while at school, he performs the practical part of the course with face-to-face education and the opportunity to learn by experience.

References

Baker, J. W. (2000). *The Classroom Flip, Using web course management tools to become the guide by the side*. In J. A. Chambers (Ed.), Selected Papers from the 11th International Conference on College Teaching and Learning (pp. 9-17). Florida Community College.

Bayır, M. (2024). Blended Learning Model. *Journal of Turkic Civilization Studies*, 5(1), 171-186.

Bergmann, J., & Sams, A. (2012). Flip Your Classroom: Reach Every Student in Every Class Every Day (pp. 120-190). Washington DC: *International Society for Technology in Education.*

Bishop, J. L., & Verleger, M. A. (2013). *The Flipped Classroom: A Survey of the Resea*rch. 120th American Society for Engineering Education Annual Conference and Exposition, 30, 1-18.

Bozdağ, H. C., & Gökler, İ. (2023). Digital Content Design for Flipped Classroom Model: Biology Course Example. *Journal of Computer and Education Research*, 11(21), 335-355. https://doi.org/10.18009/jcer.1246524.

Bulut, R., & Bekdemir, M. (2024). The Effect of the Flipped Classroom Model on Students' Mathematics Achievement, Attitude and Anxiety. *Abant İzzet Baysal University Journal of Education*, 24(3), 1479-1497. https://doi.org/10.17240/aibuefd.2024..-1407709

Çenberci, S., Çalışkan Karakulak, B., & Tol, H. Y. (2023). Investigation of Students' Views on the Flipped Classroom Model. *Journal of Computer and Education Research*, 11(22), 767-799. https://doi.org/10.18009/jcer.1337303

Çınar, M., & Ünsal, H. (2024). The Effect of the Middle School Mathematics Course Designed According to the Flipped Classroom Model on Students' Academic Achievement and Motivation. *National Education Journal*, 4(8), 20245. Received by https://uleder.com/index.php/uleder/article/view/534

Bulut, R., & Bekdemir, M. (2024). The Effect of the Flipped Classroom Model on Students' Mathematics Achievement, Attitude and Anxiety. *Abant İzzet Baysal University Journal of Education*, 24(3), 1479-1497. https://doi.org/10.17240/aibuefd.2024..-1407709

Çenberci, S., Çalışkan-Karakulak, B., & Tol, H. Y. (2023). Investigation of Students' Views on the Flipped Classroom Model. *Journal of Computer and Education Research*, 11(22), 767-799. https://doi.org/10.18009/jcer.1337303

Çınar, M., & Ünsal, H. (2024). The Effect of the Middle School Mathematics Course Designed According to the Flipped Classroom Model on Students' Academic Achievement and Motivation. *National Education Journal*, 4(8), 20245. Received by https://uleder.com/index.php/uleder/article/view/534

Davies, R. S., Dean, D. L., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development*, 61(4), 563–580.

Eastman, P. (2015). *Blended Learning Design Guideline*. Washington, DC: Office of the State Superintendent of Education Charter School Incubator Initiative

Ezentaş, R., & Karakaş, T., (2021). Review of Studies on the Flipped Classroom Model in Mathematics Education. *Turkish Studies Educational Sciences*, vol.16, no.5, 2261-2273.

Flipped Learning Network [FLN] (2014). *The four pillars of F-L-I-P*. Retrieved from http://flippedlearning.org

Hoffman, E. S. (2014). Beyond the flipped classroom: Redesigning a research methods course for e3 instruction. *Contemporary Issues in Education Research*, (CIER), 7(1), 51-62.

Horn, M. B., & Staker, H. (2017). *Blended: Using disruptive innovation to improve schools*. John Wiley & Sons.

Ingram, D., Wiley, B., Wyberg, T., & Wahlstrom, K. (2014). *A Study of the Flipped Math Classroom in the Elementary Grades.* Saint Paul, MN: University of Minnesota, College of Education and Human Development, Center for Applied Research and Educational Improvement.

İşman, A. (2011), *Distance Education*. Ankara: Pegem Academy Publishing

Kaya, D. (2018). The Effect of Flipped Learning Model on Secondary School Students' Class Participation in Mathematics Education. *Sakarya University Journal of Education*, 8(4), 232-249. https://doi.org/10.19126/suje.453729

Lage, M. J., Platt, G. J., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *The journal of economic education*, 31(1), 30-43.

Mazur, E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice Hall.

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The internet and higher education*, 25, 85-95. http://dx.doi.org/10.1016/j.iheduc.2015.02.002

Öztürk, T., Karademir, T., Yılmaz, G. K., & Yılmaz, R. (2015). *Examining flipped classroom model from students' point of view*. In EDULEARN15 Proceedings (pp. 7882-7882).

Serçemeli, M. (2016). A New Approach Proposal in Accounting Education: Flipped Classrooms. *Accounting and Finance Journal* (69), 115-126. https://doi.org/10.25095/mufad.396664

Staker, H., & Horn, M. B. (2012). *Classifying K–12 blended learning*. CA: Innosight Institute.

Talbert, R. (2012). Inverted Classroom. *The Internet and Higher Education*, 15, 89-95.

Taskin, G., and Aksoy, G., (2023). Hybrid Learning Model: A Theoretical View. XVI. *International Congress of Educational Research* (pp.75-80). Sivas, Turkey.

Tekin, O., & Emmioğlu- Sarikaya, E. (2020). Application of the flipped classroom model in high school mathematics course. *Bartın Faculty of Education Journal*, 9(2), Article 2. https://doi.org/10.14686/buefad.559990

Temizyürek, F., & Unlu, N. A. (2015). An example of the use of technology as a material in language teaching: ‚flipped classroom'. *Bartın University Faculty of Education Journal*, 4(1), 64-72. http://doi.org/10.14686/BUEFAD.2015111015

Tucker, B. (2012). Online instruction at home frees class time for learning. *Education Next*, 12(1), 82-83.

Turan, Z., & Göktaş, Y. (2015). A New Approach in Higher Education: Students' Views on the Flipped Classroom Method. *Journal of Higher Education and Science* (2), 156-164.

Ünlütürk, A. Ö., & Bakioğlu, B. (2023). Student views on out-of-school science education structured with flipped learning. *Kocaeli University Education Journal*, 6(1), 124-140. https://doi.org/10.33400/kuje.1225945

Ünsal, H. (2010). A New Learning Approach: Blended Learning. *Journal of National Education*, 40(185), 130-137.

Ünsal, H. (2018). Flipped Learning and Some Application Models. *Gazi Journal of Educational Sciences*, 4(2), 39-50.

THINKING SKILLS AND CREATIVE THINKING IN MATHEMATICS EDUCATION

Aybüke ÖZ[1], Fatma ERDOĞAN[2]

Abstract

Thinking is a cognitive process. This process is the most important part of the process of acquiring, understanding and learning information. It is also the basis of questioning, evaluating and producing new information (Güneş, 2012). Creativity "includes the skills of creating new ideas, searching and finding alternatives, adapting to a new approach, exploring existing options, encouraging assumptions" (Altın and Saracaloğlu, 2018). There is an increasing focus on enabling all students to develop creative thinking skills in mathematics. Creative thinking is a type of thinking that is inventive, produces new ideas or brings new solutions to existing problems and enables the emergence of one's own original thoughts. This study is a research on thinking skills in mathematics education and the creative thinking characteristics that have become widespread within these skills.

Keywords: Thinking, Thinking Skills, Creative Thinking, Creativity, Mathematics Education

Introduction

Thinking can be defined as the mental behaviors of an individual towards changes that occur in their inner world or physical environment. Activities that are put forward to produce solutions to a problem, obstacle or issue can be considered as the individual's thinking processes (Gömleksiz & Kan, 2009). Thinking is a complex cognitive process in which individuals analyze problems, make sense of them and produce innovative solutions using their knowledge, experience and emotions. This process provides individuals with

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the opportunity to develop different perspectives on events, make logical and structured inferences and create innovative ideas (Lucas & Spencer, 2017; Runco, 2014). In the process of creating innovative ideas, we encounter the concept of creative thinking.

Creative thinking skills are of vital importance in individuals' processes of solving complex problems, making decisions, and contributing to social development (Arı & Boyraz, 2023). Creative thinking allows individuals to combine their existing knowledge in different ways to create new ideas. Creative thinking is a way of thinking that is inventive, seeks innovation, or provides new solutions to old problems and enables the emergence of original ideas (Hançerlioğlu, 2000). Creative thinking is free, dynamic, and a productive process. Thus, in mathematics education, multiple solutions to problems are found thanks to the creative thoughts produced in the face of a problem.

Creativity is to produce new information by using the relationships between the information at hand. Although creativity and creative thinking do not mean the same thing, they are two concepts that can be used interchangeably. However, creative thinking evokes more mental activities, while creativity evokes both mental and performance-based activities (Demirel, 2010).

Purpose of the Study

The purpose of this study is to collect information on thinking skills used in mathematics education and creative thinking, which is the most popular of these skills. For this purpose, the research focused on productive thinking skills by examining the literature that can be accessed on the subject from a broad perspective.

Research Method

In this study, the document analysis method, which is a qualitative research method, was used. Document analysis is a method in which written sources, documents or records containing information about the subject to be researched are systematically examined (Fırat, 2019). In this context, documents are examined and analyzed to reach data according to the goal of the research (Çepni, 2010).

Study Group

The study group of the research consisted of articles and theses written on thinking skills and creative thinking in mathematics education obtained from digital sources.

Data Collection Tool

In the research, a systematic review was conducted among the studies written on thinking skills and creative thinking in mathematics education and data were collected with this method. Systematic review is the process of objectively scanning the original studies published on a specific subject in order to find an answer to the research question on that subject, selecting the appropriate ones according to certain criteria and synthesizing them (Denyer & Tranfield, 2009; Siddaway, Wood & Hedges, 2019). This process was carried out in a methodologically structured manner appropriate to the purpose of the research.

Data Analysis

A systematic review was conducted from sources written on thinking skills and creative thinking in mathematics education. Systematic review is a scientific research method that aims to examine the existing literature on a specific subject in a planned, structured and objective manner. It is generally used to obtain the most reliable and comprehensive information regarding the research question (Denyer & Tranfield, 2009; Siddaway, Wood & Hedges, 2019). This process was carried out in accordance with the purpose of the research.

Conclusion

The most important feature that distinguishes the individual from other living groups is the act of thinking. Because the individual is a being with reason and language skills, and the development of these skills also contributes to the act of thinking (Tahiroğlu and Gevrek, 2021). Thinking skills are mental competencies that enable the individual to learn effectively and in depth, and to be successful in problem-solving and decision-making processes. These skills operate at both cognitive and metacognitive levels and are aimed to be developed at all levels of education.

Creative Thinking is a way of thinking that is inventive, innovative, produces new and different solutions to problems, and enables the emergence of original thoughts. In other words, it is flexible, fluent, original, and unconventional thinking. It allows for the production of new ideas and possibilities, and reaching more than one correct answer. Creative thinking is defined as the process of transforming existing knowledge and experiences into original, innovative, and valuable products, solutions, or ideas. In this process, the individual blends logical thinking with intuitive thinking and goes beyond conventional thinking patterns.

According to Kale (1994), creative thinking is a way of thinking that includes thinking processes such as grasping through intuition, designing, asking questions, making analyses and syntheses, solving problems, criticizing, and producing original solutions and knowledge. Silver (1997) argued that mathematics teachers should see creativity not only as genius or an extraordinary talent, but as a tendency or approach that should be imparted to all students. In mathematics education, researchers have used various definitions and theoretical approaches to examine the development of student mathematical creativity (Leikin & Sriraman, 2022).

Mathematics education is an interdisciplinary field that examines how mathematics is taught and learned. This field investigates how mathematical knowledge is acquired, understood, taught and applied by individuals. Mathematics education draws from both educational sciences and mathematical disciplines and aims to develop effective teaching strategies by combining pedagogical approaches with mathematical content.

Suggestions

Thinking skills go beyond just memorized knowledge and develop the ability to understand, produce, and interpret. Educational practices that support these skills positively affect both the academic and life success of the individual. It is critical for educators to act consciously and systematically in this regard in terms of acquiring 21st century skills. Creative thinking skills are a mental ability that can be developed and can be supported by various methods at both individual and educational levels. One of the methods suggested in the creativity development literature is to investigate both the creative processes and products of students in order to ensure that teaching practices reveal different aspects of creative thinking (Levenson et al., 2018).

In order to provide an education that aims to raise creative and problem-solving individuals, first of all, education programs need to be prepared in line with this and teachers need to be trained to be more sensitive in this regard. Because it is a known fact that teachers classically show more interest, understanding, attention and care to intelligent students. However, a child who is creative but not very interested in the lesson learns at least as much as other children. Their learning styles may be different.

The creative process is a dynamic, variable idea/product generation and awareness-raising stage. In this process, the person's desire for discovery, change and innovation is important in foreseeing what is unrelated to the old situation and related to the new situation and discovering hidden similarities.

References

Altın, M., & Saracaloğlu, A. S. (2018). Creative, critical and reflective thinking: Similarities-differences. *International Journal of Current Educational Research*, 4(1), 1-

Arı, S. and Boyraz, C. (2023). Higher-order thinking skills in K-12 skills education: The example of social studies course. *National Education*, 52(Special Issue), 601-626. https://doi.org/10.37669/milliegitim.1309163

Çepni, S. (2010). *Introduction to Research and Project Studies* (5th improved edition - 2010). Bursa.

Demirel Ö. (2010), *New Directions in Education*, Ankara, Pegem Publishing.

Denyer, D., & Tranfield, D. (2009). Producing a systematic review. In D. A. Buchanan & A. Bryman (Eds.), *The Sage handbook of organizational research methods* (pp. 671–689). SAGE Publications.

Firat, H. (2019). Children's Reality in Cartoons: Niloya Example, *International Turkish Literature Culture Education Journal*, Issue: 8/2 2019 pp. 1007-1033.

Gumessiz, M., & Kan, A. (2009). Determining the effectiveness of the Social Studies course curriculum in gaining critical thinking, creative thinking and entrepreneurship skills (Diyarbakır Province Example)1-2. P. *Eastern Anatolia Region Studies*. 2009:39-49.

Gunes, F. (2012). *Developing students' thinking skills*. Turkology Studies, (32), 127-146.

Hançerlioğlu, O. (2000). *Encyclopedia of Philosophy (Concepts and Movements-7)* (3rd Edition). Istanbul: Remzi Kitabevi.

Kale, N. (1994) "Education and Creativity", *Education as We Live*, 37,4-6.

Leikin, R., & Sriraman, B. (2022). *Empirical research on creativity in mathematics (education): From the waste- lands of psychology to the current state of the art. ZDM– Mathematics Education, 54(1), 1–17. https://doi. org/10.1007/s11858-022-01340-y*

Levenson, E., Swisa, R., & Tabach, M. (2018). *Evaluating the potential of tasks to occasion mathematical creativity: Definitions and measurements. Research in Mathematics Education, 20(3), 273–294. https://doi.org/10.1080/14794802.2018.1450777*

Lucas, B., & Spencer, E. (2017). *Teaching creative thinking: Developing learners who generate ideas and can think critically.* Crown House Publishing.

Runco, M. A. (2014). *Creativity: Theories and Themes: Research, Development, and Practice*. New York: Academic Press.

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology, 70*(1), 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

Silver, E. A. (1997). *Fostering creativity through instruction rich in mathematical problem solving and problem posing. ZDM Mathematics Education, 3(29), 75–80. Silverman, D. (2001). Interpreting qualitative data (2nd ed.). Sage.*

Tahiroğlu, M., & Gevrek, Y. E. (2021). *The effect of perceived parent attitudes on critical thinking tendencies on primary school 4th grades. International Journal of Education Technology and Scientific Researches, 6(16), 1218-1249. doi:10.35826/ijetsar.415*

LEARNING DIFFICULTIES IN MATHEMATICS EDUCATION

Busenur İNCİ[1], Tayfun TUTAK[2]

Abstract

Learning disability is a situation where an individual has a normal or above-normal level of intelligence but has significant difficulty compared to their peers in acquiring and using listening, speaking, reading, writing, reasoning or mathematical skills. These difficulties are not caused by vision, hearing, motor disabilities, mental disabilities, emotional disorders or environmental, cultural or economic disadvantages (Ministry of National Education [MEB], 2018). Mathematics learning disability is a situation where an individual has a normal or above-normal level of intelligence but has persistent and significant difficulties in learning mathematical concepts, applying operations, solving problems and acquiring basic skills related to numbers. This condition is usually defined with the term "dyscalculia" and is caused by deficiencies in cognitive processes (Alkan & Yazıcı, 2020). These difficulties make it difficult for students to perform mathematical operations. Therefore, students experiencing this condition should be educated using individual activities, concrete materials, and technology. Individual differences of students should be taken into consideration. This study is a research conducted to explain learning difficulties experienced in mathematics education.

Keywords: Dyscalculia, mathematics education, mathematics learning difficulty, learning disability

Introduction

Students with learning difficulties in mathematics have difficulty especially in learning basic operations, recognizing symbols, following the order of operations and developing problem-solving strategies. Developing effective teaching

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strategies for these students; taking into account individual differences, using concrete materials and utilizing technology-supported teaching methods are of great importance (Baki, 2014; Sarı, 2012). Mathematical learning difficulties experienced by students can arise not only from individual deficiencies but also from inadequate teaching methods, lack of materials and inappropriate learning environments (Karataş & Güven, 2021). These difficulties are concentrated in basic areas such as four-operation skills, problem solving, number concept, algebraic thinking and geometry. Such difficulties encountered in the learning process can negatively affect students' academic success and cause them to move away from mathematics in the long term (Özsoy, 2018).

Mathematics education plays a key role in developing students' logical thinking, problem-solving and analytical skills. However, many students, especially at the middle school level, face various difficulties in learning mathematics. During this period, students expand their basic arithmetic knowledge and become familiar with more abstract mathematical concepts. This transition process can be complex and challenging for some students (Altun, 2022). It is emphasized in the literature that diagnosing dyscalculia at an early age is of critical importance for the individual to progress more healthily in their educational life. However, it is seen that the level of awareness of this learning disability in Turkey is not yet at the desired level (Özdemir, 2021). Therefore, teachers and parents need to be informed.

Purpose of the Study

The purpose of this study is to examine the causes of learning difficulties experienced in mathematics education. This study aims to both increase the awareness level of teachers and provide more efficient mathematics education to students.

Method of the Study

In this study, the document analysis method, which is one of the qualitative research methods, was used. Document analysis is a method in which written sources, documents or records containing information about the subject to be researched are systematically examined (Fırat, 2019). In this context, documents are examined and analyzed to reach data according to the goal of the research (Çepni, 2010).

Study Group

The study group of the study consisted of articles and theses written on learning difficulties in mathematics education that could be accessed.

Data Collection Tool

In the study, a systematic review was conducted among the studies written about learning disabilities in mathematics education and data was collected with this method. Systematic review is the process of objectively scanning the original studies published on a specific topic in order to find an answer to the research question on that topic, selecting the appropriate ones according to certain criteria and synthesizing them (Denyer & Tranfield, 2009; Siddaway, Wood & Hedges, 2019). This process was carried out in a methodologically structured manner appropriate to the purpose of the research.

Data Analysis

A systematic review was conducted from the sources written on learning disabilities in mathematics education in the study. Systematic review is a scientific research method that aims to examine the existing literature on a specific topic in a planned, structured and objective way. It is usually used to obtain the most reliable and comprehensive information about the research question (Denyer & Tranfield, 2009; Siddaway, Wood & Hedges, 2019). This process was carried out in a manner appropriate to the purpose of the research.

Conclusion

This study aims to examine the variety of difficulties students encounter in the process of learning mathematics and the reasons for these difficulties, and to offer various inferences regarding the teaching process. The findings show that difficulties in understanding mathematical concepts are largely related to factors such as deficiencies in students' previous learning, anxiety towards abstract concepts and inadequacy of teaching methods (Altun, 2020). It has been observed that learning difficulties are not only related to cognitive but also to affective factors; students' mathematics anxiety, lack of self-confidence and negative learning experiences are determinants of success (Ünlü & Ertekin, 2018). Dyscalculia is a specific learning disorder characterized by significant difficulties in learning and applying mathematical concepts, regardless of the individual's intelligence level. This situation can negatively affect not only the individual's academic success, but also their daily life skills and psychological well-being (Özdemir, 2021).

Knowing the difficulties that students face in any subject is an important first step for studies on learning. Synthesizing and connecting such information with subsequent studies will be considered an important basis for organizing future curricula and creating a teaching model (Rasmussen, 1998). Tall (1993) stated that there are various studies conducted to investigate learning difficulties in mathematics and classified some of these difficulties as; (1)

inadequate understanding of basic concepts, (2) inability to formulate word problems mathematically, and (3) deficiencies in algebraic, geometric, and trigonometric skills. The importance of early diagnosis should be emphasized in order to increase the academic success of students with learning difficulties in mathematics. Especially at the primary school level, the effective use of diagnostic tools and the active role of guidance services in this process can positively affect success in the long term (Çakıroğlu & Melek, 2018).

Research findings show the necessity of developing individualized education programs for students with learning difficulties in mathematics. The use of concrete materials, technology-supported education practices, and student-centered teaching strategies contribute positively to the learning processes of these students (Arslan, 2021; Korkmaz & Erdem, 2018). In addition, the research revealed that teachers have limited strategies to cope with learning difficulties and mostly prefer traditional teaching methods (Kayan & Haser, 2019). Mathematics teaching remains more abstract than other courses. This makes it difficult for students to learn mathematical concepts. Students' attitudes towards not being able to learn complex concepts, in other words their self-efficacy perceptions towards the courses, also affect their learning difficulties. Learning difficulties experienced in mathematics education include not only cognitive but also affective reasons. As a result, in order to overcome mathematics learning difficulties, a systematic and multifaceted approach should be developed not only for students but also for teachers and curriculum.

Suggestions

It is important that mathematics teachers are supported with professional development programs regarding teaching strategies for students with learning difficulties. Constructivist approaches, use of concrete materials and differentiated teaching techniques can be included in in-service training (Baki, 2014).

Students with learning difficulties should be diagnosed early and supported with individualized education programs. In this process, an effective collaboration can be established between classroom teachers and guidance services (Çakıroğlu & Melek, 2018).

In teaching mathematical concepts, especially at the primary school level, concrete materials and activities associated with daily life should be used. This will facilitate the understanding of abstract concepts (Kayan & Haser, 2019).

National education programs should be made flexible to take into account the individual differences of students. Student-centered programs based on learning by doing and experiencing can be developed (Altun, 2020).

Affective factors such as mathematics anxiety and lack of self-confidence also increase learning difficulties. For this reason, psychological counseling services should be expanded in school environments and programs can be created for the emotional needs of students (Ünlü & Ertekin, 2018).

Raising awareness in families is also an important factor in the fight against dyscalculia. Families should be able to understand the difficulties their children are experiencing and a supportive learning environment can be created at home (Shalev & Gross-Tsur, 2001). Learning difficulties in mathematics education depend on more than one factor. In this case, education can be provided by paying attention to multiple educational environments and individual differences.

References

Alkan, M., & Yazıcı, E. (2020). A case study on determining mathematics teachers' awareness of mathematics learning disabilities (dyscalculia). International Journal of Educational Sciences, 7(1), 1–20. https://dergipark.org.tr/tr/pub/uebd/issue/53761/720986

Altun, M. (2020). Primary school mathematics education (14th ed.). Current Publications.

Altun, M. (2022). Primary school mathematics education (17th ed.). Current Publications.

Arslan, M. (2021). Teaching strategies for students with mathematics learning disabilities. Journal of Research and Development in Education, 11(2), 105-118.

Association, San Diego, CA. Downloaded: 10.01.2006, http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/8 0/15/8e/cb.pdf

Baki, A. (2014). Mathematics education from theory to practice. Harf Education Publishing.

Cakiroglu, E., & Melek, D. (2018). Difficulties encountered in teaching students with learning difficulties in mathematics. Theory and Practice in Education, 14(1), 67–86.

Çepni, S. (2010). Introduction to Research and Project Studies (5th edition - 2010). Bursa.

Denyer, D., & Tranfield, D. (2009). Producing a systematic review. In D. A. Buchanan & A. Bryman (Eds.), *The Sage handbook of organizational research methods* (pp. 671–689). SAGE Publications.

Fırat, H. (2019). Children's Reality in Cartoons: Niloya Example, International Turkish Literature Culture Education Journal, Issue: 8/2 2019 pp. 1007-1033.

Karataş, İ., & Güven, B. (2021). Difficulties encountered in teaching mathematics and solution suggestions. Mathematics Education Journal, 5(1), 23–38. https://doi.org/10.xxxx/med.2021.23

Kayan, M., & Haser, Ç. (2019). Teaching strategies of mathematics teachers for students with learning difficulties. Education and Future Journal, 15(2), 25–42. https://doi.org/10.30786/jeg.567489

Korkmaz, Ö., & Erdem, E. (2018). Technology-supported teaching practices for students with learning disabilities in mathematics. Journal of Educational Technologies Research, 4(3), 210-225.

Ministry of National Education (MEB). (2018). Special education services regulation.

Özdemir, A. (2021). Dyscalculia and difficulties encountered in education: A review study. Journal of Education and Society Research, 8(2), 45–60. https://dergipark.org.tr/tr/pub/etad

Özsoy, G. (2018). Investigation of students' attitudes towards mathematics course. Journal of Educational Sciences Research, 8(1), 45–59.

Rasmussen, C. L. (1998) Reform in Differential Equations: A Case Study of Students' Understandings and Difficulties. *The Annual Meeting of American Educational Research*

Sari, H. (2012). Teaching strategies for students with learning difficulties in mathematics. Journal of Education and Teaching Research, 1(3), 45–58.

Shalev, R. S., & Gross-Tsur, V. (2001). Developmental dyscalculia. *Pediatric Neurology*, *24*(5), 337–342. https://doi.org/10.1016/S0887-8994(00)00258-7

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology, 70*(1), 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

Tall, D. (1993). Students' difficulties in calculus, Proceedings of Working Group 3 on Students' *Difficulties in Calculus*. ICME-7, Quebec, Canada, 13– 28.

Ünlü, M., & Ertekin, E. (2018). The relationship between mathematics anxiety and academic achievement: A study on high school students. Educational Sciences in Theory and Practice, 18(2), 345–362.

MATHEMATICAL LEARNING DISABILITY (DYSCALCULIA): NEUROBIOLOGICAL BASIS, DIAGNOSIS PROCESSES AND EDUCATIONAL INTERVENTIONS

Özge YAŞA[1], Tayfun TUTAK[2]

Abstract

The aim of this study is to evaluate mathematical learning disability (dyscalculia) within the scope of neurobiological foundations, diagnostic processes and educational interventions. The research is presented under these three headings and is a compilation study. The literature review method was used as a method in this study. This research was prepared by using 6 articles and 2 theses that could be reached as a result of the literature review. There is no study group in this research. The literature review method, which is one of the qualitative research methods, was used as a data collection tool in this study. The descriptive analysis method was used in the analysis of the data obtained from this study. As a result of the research, it was concluded that neurobiologically dicalculia occurs due to various differences in the brain and may be genetic. In the diagnostic process, it has been concluded that there is no diagnostic tool that diagnoses dicalculia 100%. In educational processes, various clues can be given and time can be given due to the student's memory weakness and slow processing problem. More studies can be done to create awareness about dicalculia.

Keywords: Dyscalculia, Learning Disability, Math Anxiety, Educational Intervention

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Introduction

Dyscalculia is derived from the Greek words "dis" (disorder) and Latin "calculare" (calculation) (Mutlu, 2016). In our country, this word is used as "dyscalculia" or "mathematical learning disorder" in the relevant literature (Sezer and Akın, 2011). Dyscalculia is the situation where an individual with normal or above intelligence, despite receiving an education appropriate for his/her age, exhibits success well below the mathematical performance expected from his/her age and intelligence level, does not have a sense of number and is approximately two or more years behind his/her peers (Mutlu, 2020). Learning disability is a condition that does not occur as a result of mental retardation, lack of perception or education-related factors, but can occur as a result of dysfunction in the brain, emotional or behavioral disorders. It is a retardation, disorder or delayed development in learning processes such as speaking, reading-writing and arithmetic (Kirk, 1963). Learning disability; A state of significant educational maladjustment (Bateman, 1965). Dyscalculia, one of these, is a learning disability in mathematics. It has been defined as a learning disability defined by the inability to make accurate and serial calculations and to learn basic arithmetic operations. Similarly, in Turkey, dyscalculia is expressed as "arithmetic (mathematics) disability", "mathematics learning disability" or "mathematics learning disorder" (Bintaş, 2007; Mutlu, 2016; Sezer and Akın, 2011; Soylu, 2020). Dyscalculia does not mean mental deficiency or low success. It is a learning disability and the intelligence of these students may be bright or superior (Mutlu, 2016). According to Chinn (2004), a student with learning disability processes data slowly and therefore cannot perform arithmetic operations quickly. Psychology and other sciences have not been able to determine the roots of mathematics learning disability in general. Therefore, many factors such as consanguineous marriage, genetic factors, blood incompatibility, negative situations experienced by the mother during pregnancy, smoking, alcohol or wrong drug use, and problems within the family can cause dyscalculia. In addition, dyscalculia is more common in identical twins and less common in fraternal twins and other siblings (Alarcon, et al. 1997). Based on all this information, dyscalculia can be considered a genetic disease. The term developmental dyscalculia was first defined by Kosc (1974) as "difficulty in mathematics due to a disorder in certain parts of the brain involved in mathematical cognition, without a general difficulty in cognitive functions" (Mutlu & Akgün, 2017). The term developmental dyscalculia refers to a cognitive disorder experienced in childhood that disrupts the normal acquisition of arithmetic skills (Köroğlu, 2008). Shalev and Gross-Tsur (2001) defined dyscalculia as "Developmental dyscalculia is a common cognitive disability; its prevalence in the school population is approximately 5-6%, a frequency similar to developmental dyslexia and attention deficithyperactivity disorder" and expressed the prevalence of dyscalculia (Saygı, 2023). Dyscalculia is a specific learning disorder in which a person has difficulty understanding number-related concepts and has difficulty performing arithmetic operations (Saygı, 2023). Students with dyscalculia have difficulty understanding simple number concepts and cannot intuitively understand numbers (Mutlu, 2020). Mathematics learning disability is a permanent condition. Mathematics learning disability is a persistent condition that affects the ability to acquire mathematical skills despite a desired education (Chinn, 2004).

Purpose of the Study

The purpose of this study is to evaluate mathematical learning difficulties within the scope of neurobiological foundations, diagnostic processes and educational interventions.

Method

Research Model

In this study, the neurobiological foundations, diagnostic processes and educational interventions of dyscalculia were examined. Therefore, the literature review method was used as the method in this study. Literature review is an organized analysis that includes critical evaluation of previously conducted studies. It provides the researcher with a theoretical and methodological basis on the subject he/she is studying (Hart, 1998).

Working Group

A working group was not directly established in this study. Since the focus of the study was to evaluate mathematics learning difficulties through literature review, the main data sources of the study were existing academic publications, articles, reports and other relevant literature. In this context, various academic sources were examined and literature review was conducted on dyscalculia, aiming to provide a broad perspective on the subject and to evaluate the existing information in depth.

Data Collection Tool

In this study, a synthesis was created by considering articles, theses, reports and academic books published in journals for the collection of data. The scanning sources included databases such as Google Scholar. The literature between the years 2000–2024 was primarily considered.

Data Analysis

The descriptive analysis method was used in the analysis of the data obtained in this study. Descriptive analysis is the process of summarizing and interpreting the obtained data according to previously determined themes. In this type of analysis, the researcher often includes direct quotes from the participants and the findings are compared with the literature and interpreted (Yıldırım, Şimşek, 2018). In this study, it was analyzed under the titles of neurobiological foundations, diagnostic processes and educational interventions.

Findings

Neurobiological Findings

Although the exact cause behind dyscalculia is not known, the findings from the studies agree on the assumption that the cause is a disorder in the cognitive area where numerical operations take place in the brain due to hereditary-neurobiological reasons (Lemer et al., 2003; Piazza et al., 2010). Although the exact cause of MDD is not known, there is a consensus among researchers in the literature that it occurs genetically or brain-based (Faulkenberry & Geye, 2014; Piazza et al., 2010). Medical developments in the fields of behavioral and brain imaging that have emerged in the last decade claim that developmental dyscalculia may be due to a neurobiological system disorder where numerical quantities (the total number of elements in a set) are processed. This disorder causes difficulties in acquiring arithmetic information during learning and development (Price & Ansari, 2013).

As a result of structural brain connectivity comparisons, it was found that especially the left ATR and left SLF pathways were shorter and the white matter in the brain was less in children with learning difficulties in mathematics (Ayyıldız, 2020). These findings showed that children with dyscalculia had difficulty in processing numbers and retrieving and encoding arithmetic operations from memory. As a result of functional connectivity comparisons in the brain, it was found that children with dyscalculia had lower right medial fronto-parteal, left dorsal and hyper occipital-ODA connections (Ayyıldız, 2020). These findings can be concluded that the functional unity between the regions responsible for basic and visual processing of numbers is less in dyscalculia (Ayyıldız, 2020).

Diagnostic and Evaluation Findings: It has been determined that in individuals diagnosed with dyscalculia, scores on standard math tests are significantly lower than the age group, whereas intelligence tests show above average or normal results (Shalev & Gross-Tsur, 2001). Studies have also shown that most dyscalculia children also have cognitive or psychological disorders in addition to dicalculia. In one of these studies, it was seen that 17%

of dyscalculia children had dyslexia and 26% had hyperactivity. Therefore, it is quite difficult to make an independent diagnosis of math learning disability and there is a high probability of misdiagnosis. Some researchers consider dyscalculia as a separate disorder. Many researchers also state that learning difficulty in mathematics is an abnormality, a brain-based disorder, or a problem caused by the underdevelopment of certain parts of the brain. Although there is no full consensus on the definition of dyscalculia, most studies agree that approximately 5-7% of children have dyscalculia symptoms (Butterworth, 2005). Although learning difficulty in mathematics is thought of by many as mental retardation, there are also dyscalculia among people with special talents. For example, it is known that many artists and scientists such as actress Mary Tyler Moore, actor Henry Winkler, author, scientist and politician Benjamin Franklin, singer Cher, and author of the Anderson fairy tales Hans Christian Anderson have learning difficulty in mathematics (Akın, Sezer, 2010). However, it is also a fact that there are at least one or two children with learning difficulty in mathematics in every classroom (Mutlu, 2017).

Mutlu and Akgün (2017) designed a Multiple Filter Model based on the diagnostic methods and MÖG definitions used to identify students with learning disabilities in mathematics. In this model, teacher evaluation, dyscalculia pre-assessment test, dyscalculia screening tool, student recognition form and intelligence test were used as filters (Saygı, 2023). When we look at the diagnostic tools, the Fidan Mathematics Achievement Test and the Wechsler Individual Achievement Test were used the most (f=6, %=9.52). Other diagnostic tools include calculation performance test, dyscalculia screening tool and teacher opinion. Lewis and Fisher (2016) and Benedicto-López and Rodríguez-Cuadrado (2019) also reached similar results (Tutak, Baldemir, 2022).

Considering the studies conducted so far and included in the literature, the common characteristics or symptoms of dyscalculia may be as follows;

• Incorrect calculations due to poor memory,

• Very difficult and slow solving of operations involving basic mathematical skills,

• Inability to understand the commutative nature of multiplication and addition operations,

• Difficulty in the steps and operations used in problems,

• Errors due to carelessness,

• Problems with visual processing

• Constantly using hands, i.e. fingers, in operations,

• Difficulty comparing numbers,

• Inability to distinguish positive and negative numbers,

• Making mistakes when giving change,

• Difficulty understanding concepts such as day, week, month, seasons, etc.,

• Difficulty understanding time, location and direction,

• Difficulty in strategic planning (e.g. chess game),

• Inability to remember and understand concepts in mathematics,

• Difficulty understanding fractions,

• Inability to memorize numbers,

• Confusion with mathematical symbols,

• Difficulty understanding daily life problems and sequencing events,

• Inability to draw and describe simple geometric shapes (Akın, Sezer, 2010).

These difficulties expressed in mathematical terms can also be seen in normal individuals. However, in order to distinguish the difficulties experienced by individuals with mathematics learning disabilities from the difficulties seen in normal individuals, tools and methods that can be used in the diagnosis of individuals with mathematics learning disabilities are needed (Soares, Evans, & Patel, 2018). Mutlu (2016), as a result of the literature review, expressed the methods used in the diagnosis of individuals with mathematics learning disabilities under four headings. The first is observation technique diagnostic methods. The second is computer-aided diagnostic methods. The third is the intervention response method. The fourth is the consistency-inconsistency method. Different tests and criteria are used in these methods in the literature (Butterworth, 2005). Since there is no standard and clear method in the diagnosis of individuals with mathematics learning disabilities, there is no clear information about the prevalence of dicalculia, so it is expressed in different ways in the literature (Şimşek, Arslan, 2022).

With the development of science and technology, many tools can be produced. There are also tools that can diagnose dyscalculia. One of these tools is the dyscalculia separator developed by Butterworth (2003). The first purpose of this tool is to measure the instinctive numerical competence of children between the ages of 6 and 14 (Akın, Sezer, 2010). Let's think of this tool as a kind of computer program, with this program the answers given by the person to the test questions are analyzed and the person's standard score is calculated as a result of the analysis. In order to create the composite score taken from each of the three categories, the accuracy of the answers is associated with the average reaction time (Akın, Sezer, 2010).

These three categories are

• Dot counting,

• Comparing numbers,

• Age-appropriate arithmetic skills.

1. Dot Counting: In this category, dots are given and the student is asked to express these dots in the form of numbers. An example of dot counting category questions is given in Figure 1 below.

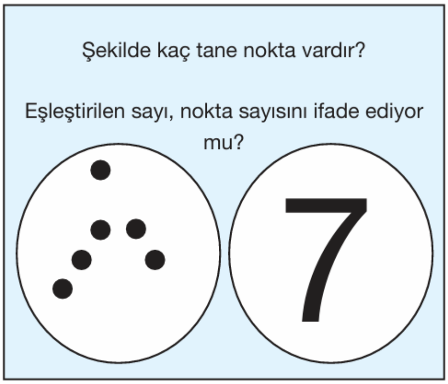

Figure 1: An example of dot counting category questions (Akın, Sezer, 2010)

In Figure 1 above, it is questioned whether a student with learning difficulties in mathematics can express the expression given with dots numerically.

2. Comparing Numbers: Here, the student's ability to compare numbers is measured.

An example of the skill of comparing numbers is given in Figure 2 below.

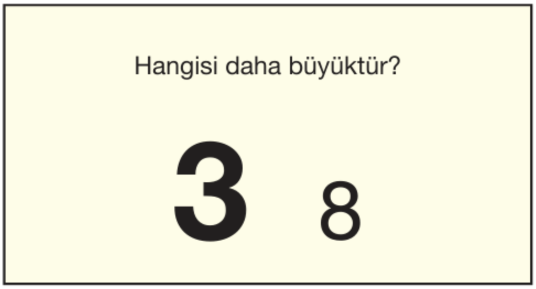

Figure 2: It is measured whether the student with learning difficulties in mathematics will choose the number that is larger in shape or the number that is larger mathematically (Akın, Sezer, 2010).

In Figure 2 above, it is questioned whether a student with learning difficulties in Mathematics can compare numerical and physical magnitudes.

3. Age-Appropriate Arithmetic Operation Skills: In this category, the student is asked for age-appropriate multiplication and addition operations.

The table for age-appropriate arithmetic operation skills is given in Figure 3 below.

Figure 3: Age-Appropriate Arithmetic Operation Skills Table also helps us with diagnosis.

Arithmetic Operation Skills	Point Counting	Comparing Numbers	Diagnosis
Low	High	High	Weak Arithmetic Skills but not Dyscalculia
Middle	Low	Low	Dyscalculia
Normal Performance	High	High	Normal Performance

(Akın, Sezer, 2010)

Figure 3: Arithmetic operation skills, we can make a diagnosis according to the table by looking at Figure 1 and Figure 2.

Although dyscalculia is the best measurement tool for diagnosing a child with dyscalculia, some schools abroad cannot provide this tool for various reasons. For similar reasons, it is almost impossible to have this tool in primary schools in our country, both in terms of awareness level and financially (Akın, Sezer, 2010).

Educational Intervention Findings

If a student is diagnosed with a learning disability in mathematics, there are easy methods and teaching situations that will allow us to include this student in the classroom. It has been observed that the strategies recommended for students with dyscalculia include computer-assisted learning, scenario booklets, concrete materials, games, rewarded homework, web-supported applications and methods such as "Number Talks" (Tutak, Baldemir, 2022). In 2003, British educator Trott developed some basic strategies that can help students with dyscalculia. One of these is strategies that improve mathematical problem-solving skills:

To Improve Mathematical Problem-Solving Skills,

• Problems that can be solved in many steps should be divided into understandable and small steps,

• Colored pencils should be used to highlight various parts of the question and more visual elements should be given in solving the problems (Akın, Sezer, 2010).

For General Instructional Designs,

• Various posters should be hung on the walls of the classroom to remind students of various mathematical concepts that cannot be easily recalled in their short-term memories,

• Tree diagrams or flow charts should be used to clarify operations,

• The lesson should be taught at the student's pace so that the student does not have difficulty in the lesson,

• Colored pencils should be used to ensure distinction and demonstration in mathematical problems,

• When teaching mathematical concepts and steps, hints should be given to facilitate remembering,

• Mathematical concepts should be visualized and diagrams should be used,

• Manipulatives should be used,

• Students should be allowed to use their hands and draft paper, and General repetition should be done before the exam and students with dyscalculia should be given extra time for the exam (Akın, Sezer, 2010).

Although this list is long enough, it may not meet all the needs of students diagnosed with mathematical learning difficulties. However, using these approaches in mathematics education can make it easier for all students with and without mathematical learning difficulties to learn. For children in the developmental age who have difficulty understanding mathematics, the necessary information can be provided about the nature of mathematics and the difficulties encountered, and these students can be helped by correcting their mistakes in the learning environment (Dowker, 2008). It is evaluated that peer-supported teaching (tutor) used in our country will have a positive effect on students with mathematical learning difficulties (Güler, Koca, 2024).

It is stated that education is carried out individually or in small groups by field teachers in the support education room (Güven, 2020). If the needs of students with dyscalculia cannot be met in the classroom, the student is taken from the mathematics course and subjected to mathematics course individually or with a few people. In this course, education is carried out with an individualized education plan prepared in line with the student's current situation and targeted academic goals. Individualized education plans are used in support education rooms in our country to contribute to individuals with dyscalculia (Güler, Koca, 2024). In a study investigating computer-aided teaching materials on students with learning difficulties in mathematics in our country, 3 students were given content planned according to computer-aided planned mathematics course outcomes for an average of 20 to 30 minutes on 5 weekdays. Number perception skills were examined and it was determined that these students with learning difficulties in mathematics were faster in counting dots and comparing numbers (Mutlu, 2016).

Conclusion and Discussion

This study is a literature study that aims to evaluate dyscalculia within the scope of neurobiological foundations, diagnostic processes and educational interventions. When we look at the neurobiological reasons for the difficulties experienced by students diagnosed with dyscalculia in operations and mathematical concepts, it was found that the left ATR and left SLF pathways of the brain are shorter and the white matter in the brain is less. At the same time, findings were found that dicalculia may be genetic. In the dyscalculia diagnostic processes, it is thought that no diagnostic tool can fully diagnose dyscalculia 100%. Although dyscalculia helps in differential diagnosis, it cannot be applied in Turkey and abroad for various reasons. In case of not being able to make a full diagnosis, it may cause to compare a student with dicalculia with a student who is slow in math or bad in arithmetic. When we look at the interventions that we can do in education for a student with dicalculia, various methods have been found. Some of these are giving various clues against the student's problem of forgetting mathematical concepts and visualizing mathematical concepts, giving more time due to the student's slowness and allowing them to use their hands.

Suggestions

Mathematical learning disability, namely dyscalculia, is not widely known in our country, therefore, our mathematics teachers and families can be given training that will raise awareness about dyscalculia. In this way, dyscalculia can be diagnosed more easily and intervened more easily. The changes in the structural and functional brain connections of dyscalculia children before and after a mathematics education targeting the relevant connectivity differences and the benefits of these trainings can be examined in future studies (Ayyıldız, 2020). It can be recommended that the dyscalculia indicator be applied to students who are suspected by mathematics teachers, although not to every student.

References

Akın, A. and Sezer, S. (2010). Dyscalculia: Mathematics Learning Disability, *Education in the Light of Science and Reason*, 126-127.

Alarcon, M. Defries, J. C. Gillis Light, J. & Penning ton, B. F. (1997). “A twin study of mathemati cs disability”. *Journal of Learning Disabilities*, 30, 617–623.

Ayyıldız, N. (2020). *Investigation of Structural and Functional Connectivity Related to Numerical Functions of the Brain in Mathematics Learning Disability (Dyscalculia),* Unpublished PhD Thesis, Ankara University

Baldemir, B. ve Tutak, T. (2022). An Investigation of the Studies on Dyscalculia in Turkey, *Journal of History School*, 60, 2815-2833.

Bateman, B. D. (1965). Reading Disorders: A Multidisciplinary Symposium. *Exceptional Children*, 32(2), 124-125.

Benedicto-López, P. & Rodríguez-Cuadrado, S. (2019). Discalculia: Clinical manifestations, evaluation and diagnosis. Current perspectives of educational intervention. *Relieve: e-Journal of Educational Research, Assessment and Evaluation*, 25(1)

Butterworth, B. (2003). *Dyscalculia screener: Highlighting children with specific learning difficulties in mathematics*. London: NFER-Nelson.

Bintaş, J. (2007). Mathematics education for students with learning disabilities in mathematics. *eJournal of New World Sciences Academy*, 2(4), 439-450.

Butterworth, B. (2005). The development of arithmetical abilities. *Journal of Child Psychology and Psychiatry*, 46(1), 3-18. https://doi.org/10.1111/j.1469- 7610.2004.00374.x

Chinn, S. (2004). *The trouble with maths*. London and New York: RoutledgeFalmer.

Dowker, A. (Ed.). (2008). “*Mathematical Difficulties: Psychology and Education*”. London: Elsevi er.

Faulkenberry, T. J. ve Geye, T. L. (2014). The cognitive origins of mathematics learning disability: A review. *The Rehabilitation Professional*, 22 (1), 9-16.

Guler, E. and Koca, F. (2024). Studies Examining Methods and Instructional Intervention Programs for Students with Dyscalculia. *Eurasian Journal of Social and Economic Research (ASEAD).*

Guven, D. (2020). Role and Responsibilities of the Support Education Room Teacher. *Trakya Education Journal*, 11 (1), 450-460.

Hart, C. (1998). *Doing a Literature Review: Releasing the Social Science Research.* Imagination. ISBN:97880761959755

Kirk, S. A. (1963). *Proceedings of The Conference on Ecploration into The Perceptually Handicapped Child*. Fund for Perceptually Handicapped Children, Inc. Evanson, IL.

Kosc, L. (1974). Developmental Dyscalculia. *Journal of Learning Disabilities*. 7(3):164–177.

Koroglu, E. (2008). *“DSM-IV - Diagnostic Criteria Reference Book”*. HYB Publishing, 4th Edition.

Lemer, C., Dehaene, S., Spelke, E., & Cohen, L. (2003). Approximate quantities and exact number words: Dissociable systems. *Neuropsy chologia*, 41, 1942-1958.

Lewis, K. E. ve Fisher, M. B. (2016). Taking stock of 40 years of research on mathematical learning disability: methodological issues and future direction. *Journal for Research in Mathematics Education*, 47(4), 338 371

Mutlu, Y. (2016). *Mathematics Learning Disability (Developmental Dyscalculia) Theories in Mathematics Education*. Pegem Academy.

Mutlu, Y. & Akgün, L. (2017). A model proposal for diagnosis of mathematics learning difficulty: Multi-filter model. *Elementary Education Online*, 16(3), 1153-1173. https://doi.org/10.17051/ilkonline.2017.330247

Mutlu, Y. (2020). *What is developmental dyscalculia? In* Y. Mutlu, S. Olkun, L. Akgün & M.H. Sarı (Eds.). Dyscalculia Mathematics Learning Difficulty: Definition, Characteristics, Prevalence, Causes and Diagnosis (1st Ed., 1-10). Ankara: Pegem Academy.

Piazza, M., Facoetti, A., Trussardi, A. N., Berteletti, I., Conte, S., Lucangeli, D., Dahaene, S. ve Zorzi, M. (2010). Developmental trajectory of number acuity reveaks a severe impairment in developmental dyscalculia. *Cognition*, 116, (1) 33-41.

Price, G. R. & Ansari, D. (2013). Dyscalculia: characteristics, causes, and treatments. *Nu meracy*: vol. 6: Iss. 1, Article 2. DOI: http:// dx.doi.org/10.5038/1936-4660.6.1.2

Saygı, H. (2023). *Analysis of Studies on Mathematics Learning Disability Using Document Analysis*. Unpublished Master's Thesis. Hacettepe University

Sezer, S., ve Akın, A. (2011). Teachers' opinions about dyscalculia seen in the students between the ages of 6–14. *Elementary Education Online*, 10(2), 757-775.

Shalev, R. S, Gross-Tsur, V. (2001). Developmental dyscalculia. *Pediatric Neurology*, 24(5): 337-342. doi:10.1016/s0887-8994(00)00258-7

Soares, N, Evans T. ve Patel, D. R. (2018). Specific learning disability in mathematics: A comprehensive review. *Translational Pediatric,* 7(1), 48-62. doi: 10.21037/tp.2017.08.03

Soylu, F. (2020). *Brain and genetic basis of mathematics learning disability (dyscalculia). Dyscalculia: Mathematics Learning Disability*. (pp. 37-53). Pegem Academy.

Şimşek, N. and Arslan, K. (2022). Descriptive Analysis of Studies on Mathematics Learning Disability, *Western Anatolian Journal of Educational Sciences*. 13(x), 433-449.

Trott, C. (2003)." Mathematics Support for Dyslexic Students". *MSOR Connections*, 3(4), 1720.

Yıldırım, A. and Şimşek, H. (2018). *Qualitative Research Methods in Social Sciences*. (11th Edition). Ankara: Seçkin Publishing.

PROBLEM SOLVING IN MATHEMATICS: THEORETICAL FOUNDATIONS AND APPLICATION AREAS

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Abstract

This study focuses on the basic principles, processes and instructional applications of problem solving in mathematics. Problem solving is considered as a process that develops students' mathematical thinking skills, encourages meaningful learning and enables the transfer of knowledge. In this section, the definition, history and place of problem solving in mathematics teaching are explained; Polya's four-stage problem solving model (understanding the problem, creating a solution plan, implementing the plan and checking the solution) is examined in detail. In addition, the strategies used in problem solving (finding a pattern, drawing a figure, systematic listing etc.) and the role of the teacher in providing these skills to students are emphasized. The difficulties encountered in teaching problem solving, the mistakes frequently made by students and the importance of student motivation in this process are also discussed. In addition, practical suggestions are given for the development of problem solving approaches of prospective teachers.

Keywords: Mathematics Education, Problem Solving, Problem Solving in Mathematics

Introduction

Mathematics education has an interdisciplinary structure that aims to help individuals develop high-level cognitive skills such as reasoning, modeling, making connections, and generalization. In this context, problem solving is at the center of not only mathematics teaching but also the holistic goals of education (Yıldızlar, 2001). The problem solving process is a dynamic

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thinking process that is shaped by an individual's understanding of a situation, developing solutions, and evaluating the results (Polya, 1945). As emphasized in the study by Soylu and Soylu (2006), while students generally show high success in exercises based on procedural knowledge, they experience serious difficulties in problems that require conceptual and procedural knowledge at the same time. This situation emphasizes that students need not only procedural knowledge but also strategic and reflective cognitive skills in the problem solving process (Schoenfeld, 1985).

Problem solving skills, which have become the focal point of educational systems in the 21st century, not only improve students' mathematical competence, but also their creative thinking, decision-making, and ability to cope with real-life problems (Kılıç, Samancı, 2005). In this context, problem solving in mathematics should not only be considered a pedagogical goal, but also a vital necessity. Polya's (1945) classical problem solving model provides a fundamental basis for studies in this field; it emphasizes that problem solving is a universal approach. However, the errors, cognitive loads, and conceptual deficiencies that students exhibit during the solution process indicate that problem solving should be systematically addressed in instructional processes (Karataş and Güven, 2004).

As is clearly seen in international assessment programs such as PISA and TIMSS, Turkish students show lower success than their peers, especially in questions based on conceptual thinking and problem solving (MEB, 2019).

Definition and Historical Development of Problem Solving in Mathematics Definition of Problem Solving

In the education literature, the concept of "problem" is defined as situations that require mental effort and solution strategies, which an individual cannot directly solve with their existing knowledge and skills (Morgan, 1995). In this context, problem solving is the process of an individual using their knowledge, experience and strategies to reach a goal. In the context of mathematics, problem solving is generally used for situations that require the combination of certain mathematical operations and concepts and for which the solution process is not clear (Olkun, Toluk, 2004).

Polya (1945) presented a systematic approach by dividing problem solving into four basic steps: understanding the problem, making a plan for the solution, implementing the plan, and reviewing the solution. This model is still accepted as a basic framework in teaching problem solving today. Polya's approach sheds light not only on producing solutions but also on how to teach the solution process.

In the study conducted by Soylu and Soylu (2006), it was emphasized that problem solving is related not only to mathematical operation knowledge but also to various types of knowledge such as conceptual knowledge, schematic knowledge, and strategic knowledge. In particular, conceptual knowledge deficiencies negatively affect students' processes of understanding the problem and choosing the right operation. Therefore, the problem solving process does not only consist of calculation skills, but also includes high-level cognitive competencies (Karataş, Güven, 2003b).

Conceptual vs. Procedural Knowledge Debate

An important debate in mathematics teaching that has been going on for many years is the balancing of procedural knowledge and conceptual knowledge. Procedural knowledge is based on knowing how to perform a procedure, while conceptual knowledge requires understanding why and how the procedure works (Baki, 1997). Permanent and transferable knowledge acquisition in problem solving necessitates the balanced and holistic teaching of these two types of knowledge (İşleyen, Işık, 2003). In the study by Soylu and Soylu (2006), it was emphasized that students were successful only in questions based on procedural knowledge, but had serious difficulties in problems requiring conceptual knowledge. This situation shows that a memorization-based and procedural-focused approach is still dominant in teaching processes.

Problem Types and Classifications in Mathematics

The effectiveness of the problem-solving process is closely related to the type of problem encountered, as well as the student's cognitive capacity. Classifying mathematical problems according to their structural characteristics allows for the effective application of different problem-solving strategies in the teaching process. In this section, problem types are examined and classified from various perspectives, and the reflections of each type on teaching practices are evaluated (Schoenfeld, 1985). Routine and Non-Routine Problems

One of the most common problem classifications in mathematics education literature is the distinction between routine (usual) and non-routine (unusual) problems. Routine problems are types of problems that students can solve by directly applying previously learned solutions, formulas, or algorithms. These types of problems often require following a specific order of operations and using memorized methods. Success in routine problems largely depends on the student's knowledge of operations and their ability to recall and apply previously acquired solution strategies. In contrast, non-routine problems require the student to develop new strategies, think from different perspectives, and use creative problem-solving skills. (Schoenfeld, 1985).

For example:

"There are 12 pages in a book. How many pages in 5 books?"

These types of problems can be solved directly by multiplication. Therefore, they are considered routine problems.

Non-routine problems are situations that do not include a specific solution or a direct formula, and require the student to think creatively and critically (Reusser, Stebler, 1997). These problems include trying different strategies, exploring the problem during the structuring process, and analyzing the problem situation.

Example:

"Ahmet arrives at a bus terminal at 08:00 in the morning. His bus will depart at 10:15. Ahmet is asked to suggest three different plans that he can make while waiting."

This type of problem falls into the non-routine problem class because it involves not only operations but also planning and life connections. In the study by Soylu and Soylu (2006), it was determined that students showed high success in routine exercises, but made serious mistakes in non-routine problems that included a conceptual dimension.

Verbal – Quantitative – Open-Ended Problems

Problems are also classified according to the way they are presented. Especially word problems require students to use both their mathematical skills and linguistic competence. The importance of word problems is that they develop the student's ability to build bridges between daily life and mathematical concepts (Aydoğdu, Olkun, 2004).

Example open-ended problem:

"There are 3 different products on sale in a supermarket. Create a shopping list and calculate the total cost."

These types of problems demand not only calculation from students, but also high-level skills such as making choices, comparing and justifying.

Algebraic - Arithmetic Problems

Problems can be classified according to the mathematical concepts and operations they include in their content. In this context, arithmetic problems are defined as problem types that include basic operations such as addition, subtraction, multiplication and division, and are mostly based on operational knowledge. In primary school mathematics curriculum, emphasis is usually placed on such problems in order to develop students' operational skills. Arithmetic problems, in addition to reinforcing students' operational competencies, form the basic building blocks of mathematical thinking. (Van Da Walle. 2019)

Algebraic problems, on the other hand, are more abstract structures that include variables, unknowns and equations. These types of problems require students to establish a mathematical model of a situation and use algebraic thinking skills (Dede, 2004). However, studies have shown that students have difficulty in making sense of algebraic word problems in particular (MacGregor, Stacey, 1996).

Multi-Stage and Complex Problems

Problems that require more than one operation or step are called multi-step problems. These types of problems require students not only to perform the operations in the correct order, but also to understand the meaning of each step (Polya, 1945).

In Soylu and Soylu's (2006) experimental study, the questions where students made the most mistakes were these types of multi-step problems. It was observed that students could not reach the correct solution, especially due to reasons such as incorrect application of the order of operations and making meaningless connections between concepts.

Polya's Problem Solving Steps and Applications in Education

In order to systematically teach the problem-solving process in mathematics, models based on certain stages have been developed. The most well-known and widely used of these models is the four-stage problem-solving model put forward by Hungarian mathematician George Polya (1945). Polya's approach is considered a universal method that encourages structured thinking not only in mathematics education but also in all disciplines.

Polya's Four-Stage Model

Polya offers a roadmap consisting of four basic steps for a successful problem-solving process:

Understanding the Problem

The student must carefully read the given problem and understand what is being asked, what data is given, and what information is missing. Conceptual understanding is essential in this step. It is necessary to be able to correctly establish the meaning of the expressions in the problem and the relationship of numerical data to the context (Polya, 1945)

Sample question: "Ayşe bought 12 pencils and gave 4 to her brother. How many pencils does she have left?"

Developing a Plan

After understanding the problem, a strategy for solving it should be determined. At this stage, the student's mental schemas come into play. Strategies that can be used include techniques such as drawing a table, going in reverse, establishing an equation, and searching for a pattern.

Strategy example: "Analyze what is given and requested, decide on the type of operation: subtraction."

Plan Implementation

In this step, the determined strategy is applied. It is important to perform the operations correctly and follow the plan step by step during the implementation process. Operational errors made at this stage may affect the accuracy of the result.

Sample application: 12 – 4 = 8

Reviewing and Evaluating the Result

The student checks whether the result they found is appropriate for the problem. This stage is often skipped, but it is critical for the development of problem-solving skills. Thinking of alternative ways and reviewing the operations performed are the basis of this stage.

Control: "Does the result make sense? Has Ayşe's pencils decreased? Does 8 remain when 4 is subtracted from 12?"

Use and Effectiveness in Education

Polya's model emphasizes that problem solving is not just a mechanical process; it is a process that requires understanding, planning, and thinking. This approach is particularly consistent with the constructivist teaching approach. Students reaching the result in their own way is of great importance for the permanence of learning. (Karataş Güven, 2003a) Soylu and Soylu's (2006) research has shown that students have difficulty especially in the planning and reviewing the result steps. The reason for this is that these steps are often skipped in the teacher-centered teaching approach. Students usually only learn the process, but have difficulty understanding what the process is used for in which context.

Researchers such as Reusser and Stebler (1997) have also stated that even if students understand the correct problem, their ability to make an appropriate plan for the solution is weak. This situation requires that Polya's second step be specifically addressed in the instructional process.

Heuristic Strategies in Problem Solving

What is Heuristic?

The term "heuristic" refers to the general thinking strategies that students use when a direct solution is not known in the problem-solving process. This term is derived from the Greek word "heuriskein" (to discover) and covers the conscious or intuitive methods that an individual applies in the solution process. Heuristic strategies allow students not only to know the operations but also to adapt this information to new situations (Schoenfeld, 1985).

Problem solving requires not only applying rules, but also developing strategies and being able to choose between various solution methods. In this respect, heuristics develop students' flexible, creative and critical thinking skills.

Common Heuristic Strategies

Polya (1945) and researchers who followed him have listed the main heuristic strategies that are effective in problem solving as follows:

Solving a similar simple problem: A student who encounters a complex problem first solves a simpler or similar problem and discovers similarities.

Going in reverse: A backward solution path is followed starting from the result. It is an effective approach especially in algebraic problems.

Drawing a figure, table or diagram: Visualizing the problem allows the student to establish the relationship between the data more clearly.

Guess and check: Possible solutions are tried and the correct solution is reached step by step.

Grouping and pattern searching: Especially in problems involving numbers, solutions are developed using repetitive structures and arrangements.

Simplifying the problem by eliminating data other than information: Eliminating unnecessary information makes it easier for the student to focus.

A few of these strategies can be used at the same time, and a problem can be solved in more than one way. This helps the student gain flexibility in solution (Schoenfeld, 1985).

The Effect of Problem Solving on Student Success

Relationship with Academic Success

Problem solving skills in mathematics measure not only the student's ability to perform numerical operations, but also their capacity to understand, analyze and apply mathematical concepts. Therefore, problem solving is a direct determinant of the student's conceptual depth and academic success (Baki, 1998). In the study by Soylu and Soylu (2006), it was determined that students who showed high success in exercises based on procedural knowledge had significantly lower success levels when faced with problems that included a conceptual dimension. This shows that mathematical success depends not only on the capacity to perform operations, but also on the skills of establishing meaning, reasoning and developing strategies.

Problems that involve more than one operation increase the student's cognitive load and increase the possibility of making errors. Especially in lower grades, students are seen to be weak in their ability to prioritize operations, comprehend the problem context, and create multi-step solutions (İşleyen, Işık, 2003). Therefore, problem-solving skills directly affect not only mathematical success but also the student's self-confidence, attitude towards learning, and motivation to learn.

PISA and TIMSS Findings

The most important exams where problem-solving skills are used as an important criterion in international comparisons are PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study). In these exams, students have to demonstrate not only procedural knowledge but also the ability to use this knowledge in complex, real-life problems. According to the PISA 2018 results, Turkey remained below the OECD average and exhibited low performance in high-level skills such as mathematical reasoning, problem solving and abstraction. The majority of students were able to do only basic operations; however, they were inadequate in analyzing and planning the problem, making correct mathematical models and reaching logical conclusions (OECD, 2019). TIMSS 2018 data also revealed similar results. The correct answer rate of 8th grade students in Turkey in multi-step questions requiring problem solving was low. This shows that students were limited in algorithmic operation skills but weak in problem solving strategies (MEB, 2020).

Conclusion and Recommendations for Teachers/Candidate Teachers

Conclusion

Problem solving in mathematics teaching is not only a skill; it is also a determining process in the development of students' thinking, meaning and application competencies. In the studies examined, it has been clearly revealed that students have difficulty especially in problem types that require conceptual knowledge, and they are more successful in questions based on procedural knowledge (Soylu, Soylu, 2006).

This situation points to the rote learning aspect of teaching and shows that problem solving should not be seen as just applying operations. In order for students to achieve meaningful learning, problem solving should be considered as a process that includes multidimensional skills such as planning, strategy development and evaluation (Polya, 1945).

In addition, international assessments such as TIMSS and PISA reveal that although Turkish students have a strong operational aspect in problem solving, they have difficulty with multi-step and contextual problems. This also reveals that educational policies and classroom practices should see problem solving not only as a test success but also as a cognitive and life skill (MEB, 2020).

Recommendations for Teachers and Teacher Candidates

• Prioritize Conceptual Learning.

Students should be made to understand why they are doing the operations before how they are doing them. The problem-solving process should begin with the establishment of conceptual structures, not with teaching formulas (Baki, 1998).

• Teach and Apply Heuristic Strategies.

Strategies such as going in reverse, drawing a table, and searching for patterns should be taught through direct instruction, and students should be encouraged to choose a strategy for each problem (Schoenfeld, 1985).

Use Open-Ended and Non-Routine Problems.

Problems with multiple solutions and outcomes increase students' creativity and flexibility of thinking. In this way, the relationship between mathematics and life can be established (Reusser, Stebler, 1997).

Include Problem-Posing Activities.

Students should be encouraged not only to solve the given problem, but also to produce their own problems. Problem-posing is one of the most powerful ways of deep understanding (Gür, Korkmaz, 2003).

• Evaluate the Process, Not Just the Result.

It is critical for meaningful evaluation that the student explains the solution path, explains the strategy used, and discusses why they chose that path (Çakmak, 2003).

• Encourage Students to Think Aloud.

Thinking aloud makes the students' solution process visible and makes it easier for the teacher to guide them. It also allows students to realize their own thinking processes (Soylu, Soylu, 2006).

• Use Technology Wisely.

Simulations, digital problem sets, and dynamic mathematics software are tools that will enrich students' problem-solving processes. However, technology should be the goal, not the tool.

• Join Teacher Communities for Continuous Development.

A problem-solving-focused education approach develops through collective, not individual, efforts. Utilizing Mat-der, teacher seminars, and academic journals supports teachers' professional development. These paradigms emerging in the digital age have been applied in science education (Bagır, Önal Karakoyun and Asiltürk 2022; Çelik, Önal Karakoyun and Asiltürk 2022; Önal Karakoyun and Asiltürk, 2021; Önal Karakoyun and Asiltürk, 2022) and mathematics (Nayıroğlu and Tutak, 2024; Polat and Tutak, 2025; Süzen et al., 2024) have provided important opportunities for the concretization of concepts and the more effective establishment of conceptual relationships in disciplines with abstract and complex structures. In this context, micro-learning, with its short-term, focused, and data-traceable structure, has rapidly become the "default" learning strategy not only in corporate training but also in primary and higher education.

References

Aydoğdu, T., & Olkun, S. (2004). Primary school students' success in choosing operations in standard word problems involving addition and subtraction. *Eurasian Journal of Educational Research*, 16, 27–38.

Baki, A. (1997). Educating mathematics teachers. *Medical Journal of Islamic Academy of Sciences*, *10*(3), 99–103.

Bagır, M., Önal Karakoyun, G., & Asiltürk, E. (2022). Views of science teachers on the use of artificial intelligence in education. *Internatıonal Onlıne Journal of Educatıonal Scıences*, 14(5), 1223-1234.

Baki, A. (1998). *Balancing operational and conceptual knowledge in mathematics teaching*. Atatürk University 40th Foundation Anniversary Mathematics Symposium, Erzurum.

Çakmak, M. (2003). *Evaluation of problem solving approach in mathematics lessons*. Mathematicians Association Science Corner. http://www.matder.org.tr

Çelik, R., Önal Karakoyun, G., & Asiltürk, E. (2022). Evaluation of middle school 7th grade science skill-based questions according to the revised bloom taxonomy. *International Online Journal Of Educational Sciences, 14*(3), 705-716.

Dede, Y. (2004). *Determination of strategies used by students while writing algebraic word problems as equations*. Mathematicians Association Science Corner. http://www.matder.org.tr

Gür, H., & Korkmaz, E. (2003). *Determination of problem posing skills of 7th grade primary school students*. Mathematicians Association Science Corner. http://www.matder.org.tr

İşleyen, T., & Işık, A. (2003). Conceptual and procedural learning in mathematics. *Journal of The Korea Society of Mathematical Education Series D: Research in Mathematical Education*, *7*(2), 91–99.

Karataş, İ., & Güven, B. (2003a). Methods used in the assessment of problem solving behaviors: The potential of clinical interviews. *İlköğretim-Online*, 2(2), 9–17.

Karataş, İ., & Güven, B. (2003b). *Analysis of the types of information used by 8th grade students in the problem solving process*. Mathematicians Association Science Corner. http://www.matder.org.tr

Karataş, İ., & Güven, B. (2004). Determination of problem solving skills of 8th grade students: A special case study. *National Education Journal*, 163, 100–113.

Kilic, D., & Samanci, O. (2005). The use of problem solving method in social studies course taught in primary schools. *Kazım Karabekir Education Faculty Journal*, 11, 100–112.

Korkmaz, E., Gur, H., & Ersoy, Y. (2004). *Problem posing and solving approach to teaching mathematics-II: Habits and views of prospective teachers*. Mathematicians Association Science Corner. http://www.matder.org.tr

MacGregor, M., & Stacey, K. (1996). Learning to formulate equations for problems. In L. Puig & A. Gutiérrez (Eds.), *Proceedings of the 20th Conference of the International Group for the Psychology of Mathematics Education (PME)* (Vol. 3, pp. 289–303). Valencia, Spain.

Ministry of National Education. (2019). *PISA 2018 Turkey Preliminary Report*. Directorate General of Measurement, Evaluation and Exam Services.

Ministry of National Education. (2020). *TIMSS 2019 Turkey Preliminary Report*. Directorate General of Measurement, Evaluation and Exam Services.

Morgan, C. T. (1995). *Introduction to Psychology* (A. Karancı, Trans., 10th ed.). Hacettepe University Psychology Department Publications.

Nayıroğlu, B., & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Educational Studies*, 11, 65-78. https://doi.org/10.33907/turkjes.1415591

Önal Karakoyun, G., & Asiltürk, E., (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure – Acidity/Basicity Relationship" Topic. *Acta Chimica Slovenica*, 68, 1-13.

Önal Karakoyun, G., & Asiltürk, E., (2022). The effect of heuristics on the reasoning of the pre-service science teachers on the topic of melting and boiling point. *Acta Chimica Slovenica,* 69(1), 60-72.

Polat, M., & Tutak, T. (2025). Interdisciplinary comparative analysis of science and mathematics teachers' level of technology use in teaching processes, their aims and problems encountered. *International Journal of Research in Teacher Education (IJRTE)*, 16, 34-48. https://doi.org/10.29329/ijrte.2025.1300.03

OECD. (2019). *PISA 2018 results: What students know and can do (Volume I)*. OECD Publishing. https://doi.org/10.1787/5f07c754-en

Olkun, S., & Toluk, Z. (2004). *Activity-based mathematics teaching in primary education* (2nd ed.). Anı Publishing House.

Polya, G. (1945). *How to solve it: A new aspect of mathematical method*. Princeton University Press.

Reusser, K., & Stebler, R. (1997). Every word problem has a solution: The social rationality of mathematical modeling in schools. *Learning and Instruction*, *7*(4), 309–327. https://doi.org/10.1016/S0959-4752(97)00014-5

Sabella, M. S., & Redish, E. F. (1995). Student understanding of topics in linear algebra. *University of Maryland Physics Education Research Group Technical Report*, 1–6.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. Academic Press.

Soylu, Y., & Soylu, C. (2006). The role of problem solving on the path to success in mathematics courses. *Journal of Education Faculty*, 7(11), 97–111.

Stacey, K., & MacGregor, M. (2000). Learning the algebraic method of solving problems. *Journal of Mathematical Behavior*, *18*(2), 149–167. https://doi.org/10.1016/S0732-3123(99)00030-0

Süzen, A.B., Tutak, T., İlhan, A., & Nayıroğlu, B. (2024). Teacher and student opinions on teaching four operations with ınteger numbers in 7th grade with counting stamps. *International e-Journal of Educational Studies,* 8, 142-156. https://doi.org/10.31458/iejes.1343835

Van de Walle, J. A., Karp, K. S., & Bay-Williams, J. M. (2019). *Elementary and middle school mathematics: Teaching developmentally* (10th ed.). Pearson.

Yıldızlar, M. (2001). *Methods of solving mathematical problems*. Eylül Book and Publishing House.

A CURRENT LITERATURE REVIEW ON THEORETICAL FOUNDATIONS AND APPLICATION FIELDS OF GAME-BASED MATHEMATICS TEACHING

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Abstract

This study aims to examine the theoretical foundations of the game-based learning approach in mathematics teaching, its application methods and its effects on the teaching process. Games are an effective learning tool that supports the cognitive, affective and social development of students. Contemporary theories such as constructivism, sociocultural learning, multiple intelligence theory and discovery-based learning theoretically support game-based teaching. Educational mathematics games provide the concretization of concepts, the development of operational skills and the acquisition of problem-solving strategies. Digital games enrich the learning process with their individualization, instant feedback and multi-sensory appeal features. Experimental studies in the literature reveal that teaching with games increases academic success, positively affects attitudes and improves self-confidence. However, there are also application-based difficulties such as lack of time, lack of materials, classroom management and measurement-evaluation. Therefore, it is recommended to increase in-service training for teachers, ensure integration into the curriculum and develop alternative assessment tools.

Keywords: Game-based learning, mathematics teaching, digital games, teacher views, learning theories

Introduction

Mathematics teaching is widely perceived by students as “incomprehensible”, “boring” and “difficult”, especially due to its abstract structure (Mutlu & Söylemez, 2021). This perception negatively affects not only academic success

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but also students' learning motivation, self-confidence and problem-solving skills. When students frequently fail in mathematics classes, this failure leads to negative affective outcomes such as anxiety, low self-efficacy and disinterest in mathematics over time. In this context, educators have turned to alternative methods that will attract students' attention, facilitate meaning and ensure active participation (Hui & Mahmud, 2023).

Play is an activity as old as human history and can be defined as a voluntary participation-based, fun and educational tool that contributes to both the social and cognitive development of the individual (Himmawan & Juandi, 2023). Since this definition coincides with the basic principles of education, the use of games in structured forms in education has become increasingly important (Bruner, 1966). Especially in recent years, it has been revealed that games are effective learning tools not only for the preschool period but also at primary, secondary and even high school levels. Game-based learning strategies provide great pedagogical advantages in terms of ensuring that a subject such as mathematics, which is often perceived as "abstract", connects with the student through the "concretization" process (Erşen & Ergül, 2022).

Games provide an environment that not only supports learning but also stimulates students' natural curiosity, desire to explore and courage to take risks (Gardner, 1983). In this respect, games show that learning is not only teacher-centered and one-way transfer; it is an active process that students carry out by experiencing and constructing meaning (Bruner, 1966). Indeed, constructivist learning theory also emphasizes that the individual actively constructs knowledge. Game-based learning completely overlaps with this theory; it supports students to take responsibility for their own learning process. On the other hand, principles such as multiple intelligence theory, active learning, student-centeredness and differentiated instruction, which are frequently emphasized in contemporary educational approaches, are naturally integrated with game-based instruction (Gardner, 1983). Especially in a discipline such as mathematics that aims to develop skills such as systematic thinking, establishing relationships, pattern recognition and solution generation; games are powerful teaching tools in terms of making content meaningful, making concepts apparent and providing permanent learning.

Game-based learning stands out as a multidimensional pedagogical strategy that is not only interesting but also supports cognitive, affective and psychomotor development (Himmawan & Juandi, 2023). The aim of this study is to examine the theoretical foundations, usage patterns and educational effects of games in mathematics teaching in the context of literature, and also to make contributions to the application areas of this approach. These paradigms emerging in the digital age have been applied in science education (Bagır, Önal Karakoyun and Asiltürk 2022; Çelik, Önal Karakoyun and Asiltürk 2022; Önal Karakoyun and Asiltürk, 2021; Önal Karakoyun and Asiltürk, 2022) and mathematics (Nayıroğlu and Tutak, 2024; Polat and Tutak, 2025; Süzen et al., 2024) have provided important opportunities for the concretization of concepts and the more effective establishment of conceptual relationships in disciplines with abstract and complex structures. In this context, micro-learning, with its short-term, focused, and data-traceable structure, has rapidly become the "default" learning strategy not only in corporate training but also in primary and higher education.

Thoretical Foundations: Game and Learning Theories

There are many theoretical approaches in educational science that explain the effect of play on learning. These theories reveal that play is not only a fun activity, but can also be at the center of a serious learning process. According to Jean Piaget's theory of cognitive development, play is one of the main tools in the process of discovering the child's environment and developing mental schemas (Himmawan & Juandi, 2023). Piaget argues that children gain experience through play, and that these experiences are transformed into knowledge through "assimilation" and "accommodation". In this context, play serves as a natural laboratory that serves the student's cognitive development (Himmawan & Juandi, 2023).

Lev Vygotsky, on the other hand, places play at the center of the child's zone of proximal development (ZPD) in his sociocultural learning theory. According to him, children experience conceptual development by interacting with their peers or adults during play. Vygotsky's theory provides an important basis in terms of cooperative games supporting both social and cognitive development (Himmawan & Juandi, 2023). Traces of this theory can be seen especially in group games and mathematical activities involving peer interaction. Jerome Bruner, on the other hand, considers play in the context of "discovery-based learning". According to Bruner, students actively explore, produce hypotheses, test them, and construct their own learning during play. The role of the teacher in this process is to guide, provide appropriate stimuli, and create environments that will challenge the student mentally.

Howard Gardner's theory of multiple intelligences is related to the flexible structure of games that appeal to individual differences (Gardner, 1983). Games that target numerical-logical, bodily-kinesthetic, visual-spatial or social intelligence areas allow students to learn with their own strengths. As a result, many contemporary learning theories such as constructivism, sociocultural theory, multiple intelligence approach and discovery-based learning constitute the theoretical basis of game-based learning. The intersection point of these theories is that the student takes a role in the learning process as an active, social and meaning-making individual. Under the next heading, the reflections and sample applications of these theoretical foundations in the context of mathematics education are discussed in detail.

Educational Mathematics Games and Application Examples

In order for games to be used effectively in teaching mathematics, it is not enough for them to have only an element of entertainment; games must be structured with pedagogical purposes that serve certain gains. In this direction, educational mathematics games (EMG) are tools developed based on both game dynamics and teaching objectives (Russo, Russo, & Bragg, 2018). EMOs allow children to acquire basic mathematical skills such as counting, doing operations, sorting, creating patterns, problem solving and developing strategies in a fun and interactive way.

Mutlu and Söylemez's (2021) field applications, especially with children with dyscalculia (difficulty learning mathematics), show that EMOs cause significant improvements in processing skills and concept understanding. At the same time, games reduce children's mathematical anxiety and increase their desire to participate in lessons. Educational mathematics games are mostly structured and goal-oriented. Examples of such games and their application purposes are listed below:

• "Come on, Match": Aims to match numbers with dot representations. Develops number perception and representation awareness.

• "Number is in Me – Multiplicity is in Me": A card matching game where numbers are represented in different ways. Strengthens concept matching and classification skills.

• "Fold the Honeycombs": A game that aims to reach the target number using multipliers. Supports strategic thinking and mental calculation skills.

• "Find the Number 24": Aims to reach the number 24 using four operations together. Includes operation priority, mental flexibility and trial-and-error methods.

These games can be implemented individually or in groups. Group games also contribute to the development of cooperation, communication and social skills. The fact that students are more courageous in making mistakes during the game is due to the low-risk atmosphere offered by the game environment. Mistakes become a natural part of the learning process, which supports deep learning. It is suggested that educational games must comply with some basic principles in order to be effective. The five principles developed by Russo, Russo and Bragg (2018) are as follows:

1. Student Participation: The game should be engaging and fun, and should draw the student in.

2. Balance of Skill and Luck: The game should include both elements of luck and structures that require cognitive effort.

3. Math-Centered Content: The game should directly target mathematical concepts.

4. Adaptability: The game should be easily adaptable to different levels and student characteristics.

5. Home-School Connection: Games should be structured to support learning not only in the classroom but also at home.

These principles determine the basic orientations that should be taken into consideration when designing games or restructuring existing games for educational purposes. Integrating the games that mathematics teachers select by considering these principles into their lesson plans will increase the effectiveness of teaching with games. In the next section, the role and potential of games supported by digital technologies in teaching mathematics is discussed in detail.

Digital Games and Their Role in Mathematics Teaching

Today, technology has become an indispensable tool in educational environments. Digital games, in particular, offer customizable and multi-sensory learning environments that can directly affect students' cognitive processes, thus creating an alternative to traditional teaching methods (McLaren, Adams, Mayer, & Forlizzi, 2017). In teaching a symbolic and abstract subject such as mathematics, the visual, interaction, and feedback advantages provided by digital games carry pedagogical potential (McLaren, Adams, Mayer, & Forlizzi, 2017).

Digital educational games (DEGs) provide differentiated learning environments that are suitable for students' individual learning speed and level. For example, students can receive instant feedback after making a mistake, which allows the concept to be reinforced. In addition, DEGs encourage the development of higher-order thinking skills such as mathematical problem solving, estimation, strategy development, and error analysis within game scenarios. In a systematic review conducted by Himmawan and Juandi (2023), it was stated that digital mathematics games have positive effects on students' calculation accuracy, speed, concept understanding, and general success. Similarly, Hui and Mahmud (2023) examined the effects of game-based learning on cognitive (knowledge acquisition, concept development) and affective (motivation, interest, attitude) areas and emphasized that significant gains were achieved.

The pedagogical advantages of digital math games can be listed as follows:

• Individualization: Games can be automatically adapted according to the student's level and performance.

• Instant Feedback: Incorrect operations can be corrected immediately, which reinforces learning.

• Increased Motivation: Interactive structures keep the student's interest alive.

• Audiovisual Support: Visualization of concepts deepens learning.

• Gamified Assessment: Provides a more natural assessment environment by reducing traditional test anxiety (Russo, Russo, & Bragg, 2018).

For example, internationally recognized digital mathematics games such as "DragonBox", "Mathletics", and "Prodigy Math" are actively used by millions of students and provide high levels of participation. In such applications, students play games while also performing tasks that include mathematical concepts such as basic operations, algebraic thinking, geometry, and ratio-proportion (Yılmaz & Yıldız, 2023).

In the context of Turkey, digital gamification applications are increasing through the EBA platform, mobile applications and various TÜBİTAK-supported projects. However, in order for these games to be effective, it is important that they are integrated with the curriculum, pedagogically guided by teachers and integrated into measurement-evaluation systems. As a result, digital games have the potential to go beyond traditional teaching methods and make learning more interactive, customized and sustainable (McLaren, Adams, Mayer, & Forlizzi, 2017). In the next section, the effects of teaching through games on students' academic success are examined together with experimental findings.

The Effect of Teaching Through Games on Academic Success

Teaching with games not only increases students' interest in the lesson, but also makes positive contributions directly to academic success. Numerous experimental and quantitative studies on this subject show that game-based learning is effective on both short-term and permanent learning. Games allow students to understand abstract concepts more easily, reduce computational errors, and use problem-solving strategies more effectively. In a quantitative study conducted by Başün and Doğan (2020), the effects of game-based teaching in 8th-grade mathematics courses were examined. Students in the experimental group participated in activities supported by games for four weeks, while the control group taught the course with traditional methods. At the end of the study, a significant increase was observed in the academic success scores of the experimental group, and a positive change was also recorded in the attitudes of these students towards mathematics (Başün & Doğan, 2020).

Similarly, in the systematic review conducted by Himmawan and Juandi (2023), it was stated that teaching with games offers multidimensional benefits such as not only accuracy of procedure but also conceptual understanding, retention of learning and reduction of cognitive load. Especially for low-achieving students, learning with games is much more effective than traditional teaching methods.

Considering that learning is not limited to the acquisition of knowledge; it also includes affective dimensions such as motivation, self-efficacy and attitude, the effect of games on academic success should be evaluated as a multi-layered process (Hui & Mahmud, 2023). For example, in a review conducted by Hui and Mahmud (2023), it was emphasized that game-based mathematics teaching extends students' attention span, provides more opportunities for repetition and increases students' self-confidence. In addition, students who play games in the classroom are more likely to learn from each other; learning becomes more permanent with peer interaction. As students become involved in the game, they become more attached to the process and their task responsibility increases. Since the game environment provides a context where failure is natural and acceptable, it contributes to the development of individuals who are willing to try and do not hesitate to make mistakes (Uğurel & Moralı, 2008).

In conclusion, the literature reveals that teaching with games increases students' academic achievement levels, supports the permanence of learning and makes the learning process more meaningful. In the next section, these effects are examined from the teacher's perspective and the strengths and difficulties encountered in the application are evaluated.

Teachers' Opinions and Field Reflections

The success of game-based teaching approaches in classroom applications is directly related to how teachers perceive this method, how they apply it, and under what conditions they use it. Therefore, teachers' opinions and application experiences are of vital importance in terms of the sustainability and dissemination of teaching with games. In the field research conducted by Mutlu and Söylemez (2021), the vast majority of mathematics teachers stated that teaching with games increases students' motivation, encourages participation, and makes learning permanent. Teachers stated that they observed that students perform mathematical operations with fewer errors during the game, participate more enthusiastically in the problem-solving process, and their social skills improve, especially in collaborative games.

However, some difficulties that teachers encounter in the process of implementing game-based teaching are also noteworthy. These include:

• Lack of time: Games often require more time than traditional methods.

• Lack of materials: Access to game materials may be limited, especially in public schools.

• Classroom management difficulties: Managing games in large and crowded classes may be difficult.

• Problem of integration into the curriculum: Games are not given enough space in the current curriculum.

• Difficulties in relating to measurement and evaluation: Inadequacy of standardized tests in academically evaluating the gains obtained during games (Erşen & Ergül, 2022).

Despite all these difficulties, the vast majority of teachers see teaching with games as a pedagogical value, but they need more support and guidance during the implementation process. In fact, in the systematic review conducted by Erşen and Ergül (2022), it was emphasized that teachers' attitudes towards game-based approaches are generally positive, but their implementation skills need to be developed (Erşen & Ergül, 2022). The following suggestions were developed in line with teachers' feedback:

1. In-service training programs should include game-based teaching content.

2. Teachers should be provided with ready-made educational game materials and instructions.

3. Teaching programs should be restructured to integrate games into the curriculum.

4. Assessment-evaluation tools should be planned in an integrated manner with games.

In this context, supporting teachers in terms of knowledge, skills and attitudes will pave the way for more effective and widespread implementation of game-based mathematics teaching.

The next section includes general results and suggestions that can be derived from this literature review.

Conclusion and Recommendations

This study has addressed the theoretical foundations of game-based mathematics teaching, its application methods and contributions to the teaching process with a multidimensional approach. The compiled literature reveals that games are not only fun activities but also powerful pedagogical tools that support the development of mathematical thinking (Yılmaz & Yıldız, 2023). Games provide active participation of students, personalize the learning process, increase motivation and contribute to permanent learning. Especially in an abstract field such as mathematics, the process of concretization and structuring concepts through games becomes more meaningful and efficient.

In the theoretical framework, the theories of pioneers such as Piaget, Vygotsky, Bruner and Gardner have revealed that learning through games encompasses not only cognitive but also social, affective and cultural dimensions. In this context, educational mathematics games should be considered as flexible and adaptable teaching tools that support multi-faceted development at both individual and group levels (Russo, Russo, & Bragg, 2018).

The findings obtained from application examples and teacher opinions show that game-based teaching increases students' academic success, contributes to the development of positive attitudes towards mathematics and increases their self-efficacy perceptions regarding the learning process (Piaget, 1951; Vygotsky, 1978). The integration of digital games brings together education with contemporary teaching technologies, provides individualized learning experiences and enriches learning especially with audiovisual support. However, the sustainability and systematic applicability of teaching with games requires some structural supports. In this context, some suggestions are presented for teacher educators and practitioners:

1. Integration into the Curriculum: Mathematics curriculum should be made flexible to make room for game-based teaching.

2. In-Service Training: Teachers should be provided with continuous training on game development and game-based teaching strategies.

3. Material and Resource Development: Age-appropriate, achievement-focused educational game materials should be developed in cooperation with the ministry and universities.

4. Technology-Supported Game Design: Local digital mathematics games should be developed and integrated into platforms such as EBA.

5. Measurement-Evaluation Harmonization: Alternative measurement tools (rubrics, performance tasks, etc.) that allow the assessment of skills acquired during the game should be used (Erşen & Ergül, 2022).

Game-based teaching is not just a method; it is a learning philosophy that makes learning more natural, meaningful and permanent. This approach positions the student as an active individual who not only receives information but also interacts with it. In a field that requires mental effort such as mathematics, games reduce anxiety about learning while also encouraging curiosity and discovery. It is hoped that in the classrooms of the future, math games will be seen not only as a tool but also as a pedagogical approach.

References

Bagır, M., Önal Karakoyun, G., & Asiltürk, E. (2022). Views of science teachers on the use of artificial intelligence in education. *Internatıonal Onlıne Journal of Educatıonal Scıences*, 14(5), 1223-1234.

Başün, A. R., & Doğan, M. (2020). The effect of game-based teaching in mathematics education on academic achievement and retention. *Journal of Instructional Educational Research*, 6(2), 12–27.

Bruner, J. S. (1966). *Toward a theory of instruction*. Harvard University Press.

Çelik, R., Önal Karakoyun, G., & Asiltürk, E. (2022). Evaluation of middle school 7th grade science skill-based questions according to the revised bloom taxonomy. *International Online Journal Of Educational Sciences, 14*(3), 705-716.

Erşen, Z., & Ergül, R. (2022). *Trends of game-based learning in mathematics education: A systematic review*. ResearchGate.

Gardner, H. (1983). *Frames of Mind: The Theory of Multiple Intelligences*. Basic Books.

Himmawan, D. F., & Juandi, D. (2023). Games based learning in mathematics education: A systematic literature review. *Union: Jurnal Ilmiah Pendidikan Matematika*, 11(1), 41–50.

Hui, H. B., & Mahmud, M. S. (2023). Influence of game-based learning in mathematics education on the students' cognitive and affective domain: A systematic review. *Frontiers in Psychology*, 14, 1105806.

McLaren, B. M., Adams, D. M., Mayer, R. E., & Forlizzi, J. (2017). A computer-based game that promotes mathematics learning more than a conventional approach. International. *Journal of Game-Based Learning*, 7(1), 36–56.

Mutlu, Y., & Söylemez, İ. (2021). *Mathematics with Games: For children with learning difficulties in mathematics*. Dyscalculia Association.

Nayıroğlu, B., & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Educational Studies*, 11, 65-78. https://doi.org/10.33907/turkjes.1415591

Önal Karakoyun, G., & Asiltürk, E., (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure – Acidity/Basicity Relationship" Topic. *Acta Chimica Slovenica*, 68, 1-13.

Önal Karakoyun, G., & Asiltürk, E., (2022). The effect of heuristics on the reasoning of the pre-service science teachers on the topic of melting and boiling point. *Acta Chimica Slovenica,* 69(1), 60-72.

Piaget, J. (1951). *Play, Dreams and Imitation in Childhood*. Routledge.

Polat, M., & Tutak, T. (2025). Interdisciplinary comparative analysis of science and mathematics teachers' level of technology use in teaching processes, their aims and problems encountered. *International Journal of Research in Teacher Education (IJRTE)*, 16, 34-48. https://doi.org/10.29329/ijrte.2025.1300.03

Russo, J., Russo, T., & Bragg, L. A. (2018). Five principles of educationally rich mathematical games. *Australian Primary Mathematics Classroom*, 23(3), 30–34.

Süzen, A.B., Tutak, T., İlhan, A., & Nayıroğlu, B. (2024). Teacher and student opinions on teaching four operations with ınteger numbers in 7th grade with counting stamps. *International e-Journal of Educational Studies,* 8, 142-156. https://doi.org/10.31458/iejes.1343835

Uğurel, I., & Moralı, S. (2008). Interaction of mathematics and games. *Gazi Faculty of Education Journal*, 28(3), 75–98.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Yılmaz, G., & Yıldız, A. (2023). Bibliometric analysis on digital game-based learning in mathematics education. *İnönü University Journal of Education Faculty*, 24(2), 327–343.

USE OF MOBILE TECHNOLOGY IN EDUCATION AND SCIENCE EDUCATION

Harun YILDIZ[1]

ABSTRACT

The use of mobile technologies in today's educational approaches is significantly transforming learning processes. Smartphones, tablets, and mobile apps, in particular, eliminate the limitations of time and space, allowing students to access learning at any time. These technologies support student-centered learning environments through functions such as providing interactive content, personalizing learning, and providing instant feedback. In the context of science education, mobile technologies facilitate the development of scientific process skills such as experimentation, observation, data collection, and analysis, and increase students' active participation in learning. Mobile-supported methods such as augmented reality (AR), sensor-based data collection tools, and virtual laboratory applications support the embodiment of science concepts and the development of students' critical thinking skills. However, strengthening teachers' digital pedagogical competencies is crucial for effectively integrating mobile technologies into the educational environment. Consequently, mobile technologies contribute to the creation of innovative and interactive learning environments in both general education and science teaching; in this context, educational policies and teacher training programs should be structured with an approach that prioritizes technology integration.

Keywords: Mobile Technology in Science Education, Student Achievement and Motivation, Accessibility

INTRODUCTION

Mobile technologies have triggered a significant transformation in education in recent years (Akpınar, 2005; Bozkurt ve Bozkaya, 2013). The proliferation

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of mobile devices, particularly smartphones and tablets, has made them the primary means of accessing learning materials (Klopfer et al., 2002; Mac Callum, 2010; Philip & Garcia, 2013; UNESCO, 2018). This development has enabled educational processes to become independent of time and space, creating a flexible learning environment where students can access learning resources anytime, anywhere (Brinson, 2015; Motiwalla, 2007; UNESCO, 2020). With the use of mobile communication technologies in education, new approaches such as distance education, blended learning, and out-of-class interaction have become a part of daily learning. Digital technologies are widely used in science (Bagır ve ark., 2022; Bulduk, 2024; Çelik et all., 2022; Çetinkaya, 2017; Erbek et all., 2023; Önal Karakoyun et all., 2025; Önal Karakoyun & Asiltürk, 2022; Önal Karakoyun & Asiltürk, 2021) and mathematics (Baldemir ve Tutak, 2024; Cırık ve Akpolat, 2024; Güneş, 2022; Nayıroğlu ve Tutak, 2024; Polat ve Tutak, 2025; Süzen ve ark., 2024) education today. This report systematically reviews the literature (2015-2025) examining the impact of mobile communication technologies on science learning, analyzing the current status and key trends. The review is presented under four main headings:

(1) Mobile communication and education – an overview of the use of mobile technologies in education;

(2) Science teaching and digitalization – a comparison of traditional science education and digital methods; (3) The concept of mobile learning – learning processes and effects through mobile devices; (4) The integration of mobile technologies into education – innovative approaches such as mobile applications, virtual laboratories, and augmented reality. Finally, the findings will be summarized and the main trends in the literature and future predictions will be discussed. [2]

Purpose of the Research

The purpose of this study is to examine the impact of mobile communication technologies on science education and to evaluate their contributions to students' academic achievement, motivation, and the learning process. Furthermore, the aim is to analyze the opportunities offered by mobile learning and its limitations, and to offer recommendations for the field.

Research Method

This research was conducted using document analysis. Within the scope of the study, academic publications published between 2015 and 2025 that address the impact of mobile communication technologies on science learning were systematically reviewed. The selected literature was evaluated through content analysis, and the data was thematically classified under four main headings:

the use of mobile technologies in education, digitalization in science education, mobile learning processes, and technological integration. The findings were interpreted using descriptive analysis, and trends and prominent themes in the literature were identified.

Data Collection Process

The research data collection process was based on a systematic review and selection of relevant literature. The primary data sources consisted of peer-reviewed articles, national and international theses, conference proceedings, and reports addressing mobile communication and mobile learning in science education. Criterion sampling, a type of purposive sampling, was employed in the literature selection process. This method selected studies directly relevant to the research problem. Selected publications met criteria such as being published in the field of science or science education, involving the use of mobile devices or applications, published within the last 10–15 years, and being open to scholarly access. National databases (ULAKBİM, Turkish Education Index, National Thesis Center) and international databases (ERIC, Scopus, Web of Science, Google Scholar) were used for the search. Searches were conducted using Turkish and English keywords (e.g., "mobile communication," "mobile learning," "science education," "science education").

Relevant studies were pre-screened based on their titles, abstracts, and keywords, and those deemed suitable were provided in full text. Approximately 25–30 qualified studies that met the criteria and were suitable for the scope of the research were included in the detailed analysis. Thus, a comprehensive and relevant literature dataset was created to examine the effects of mobile communication technologies on science learning.

Data Analysis Process

The collected literature was systematically evaluated within the framework of content analysis. Data obtained from each study were recorded in Microsoft Excel using a common coding form. The form included information such as the study's identity, research type, method, sample characteristics, mobile technology used, science topic, and key findings. The coding process was conducted independently by two researchers to ensure consistency, and any differences were discussed and resolved through consensus. Within the scope of the descriptive analysis, the distribution of studies by year, country, and method type was summarized using frequencies and percentages. In the qualitative analysis, the findings were examined thematically, and core themes were established regarding the impact of mobile communication on science learning. These themes included academic achievement, motivation, collaborative learning, attitudes, and challenges encountered. The principles of constant comparative analysis were adopted throughout the coding process, and themes were updated as necessary.

Additionally, thematic comparisons were conducted across studies to assess similarities and differences across different educational levels and geographic contexts. Consequently, quantitative and qualitative data were interpreted holistically, providing a comprehensive analysis of the impact of mobile communication on science learning. Findings were supported with examples from relevant studies and reported in line with the research objectives.

Validity and Reliability

Various methodological strategies were employed to ensure the study met validity and reliability criteria. Validity was defined as the extent to which the findings reflect reality, and inclusion criteria were meticulously determined to ensure internal validity. Care was taken to select publications that were directly relevant to the research question, of high scientific quality, and in line with the established criteria. This approach ensured that the analysis results accurately represented the relationship between mobile communication technologies and science learning. Furthermore, examining documents from different types and sources (articles, theses, reports) together created a data triangulation effect, increasing both validity and reliability.

The themes and interpretations that emerged during the analysis process were reviewed by another researcher with expertise in the field, thus ensuring impartiality and consistency in the researchers' interpretations. Any points where consensus could not be reached through expert opinion were resolved through discussion based on the literature. For reliability, the study's consistency and replicability were prioritized. The coding process was conducted independently by two researchers, and agreement between coders was assessed through comparisons. In cases of discrepancy, consensus was achieved through joint review, thus reinforcing coding consistency.

All stages of the research—database searches, selection criteria, coding procedures, and analysis steps—were documented in detail. This transparency ensures that other researchers conducting similar research can apply the same methodology and reach similar conclusions. Coding categories were clearly defined based on concepts from the literature and previous studies, which increased the internal consistency of the measurement tool. The researchers avoided subjective judgments in data interpretation and focused solely on data-based inferences. The resulting themes were based directly on the sources and supported by numerical data, demonstrating that the results were the product of a systematic analysis process rather than being random or biased.

To ensure transferability of the results, the scope and limitations of the study are clearly stated so that readers can assess the relevance of the findings to their own context. In summary, a rigorous and multifaceted methodological approach was adopted to ensure validity and reliability in this theoretical research. Scientific credibility was maximized through multiple analytical techniques, careful sample selection, systematic data analysis, and expert review.

The Effects of Mobile Communication on Science Learning: A General Assessment

The literature emphasizes that mobile technologies have significantly transformed science education, making learning processes flexible, accessible, and student-centered. Portable devices such as smartphones and tablets have enabled students to access scientific information regardless of time and space constraints, thus blurring the boundaries between formal and informal learning. Tools such as mobile apps and augmented reality support the connection between science learning and everyday life.

Extensive studies have proven that mobile learning applications have positive effects on academic achievement and motivation. Interactive content, game-based learning, and inquiry-based activities significantly improve students' comprehension and exam performance in science, while also increasing interest and participation in the course. Enabling students to self-determine their learning pace and supporting their intrinsic motivation through instant feedback plays a critical role in this success.

Mobile communication technologies offer significant advantages to the learning process, including accessibility, personalization, collaborative learning, and interaction. Students can access learning materials anytime, anywhere, and at their own pace; collaborative learning opportunities in science are increasing thanks to collaboration, data sharing, and instant communication. Touch-sensitive interfaces, simulations, and instant feedback mechanisms increase the retention and effectiveness of learning.

However, the distractions, access to misinformation, digital inequality, and difficulties faced by teachers in adapting to mobile learning are also frequently highlighted in the literature. Distractions brought on by devices through social media and games, students' exposure to unverified content, a lack of technological infrastructure, and teachers' lack of pedagogical competence can all limit the effectiveness of this method. Therefore, necessary adjustments should be made in areas such as attention management, media literacy, strengthening digital infrastructure, and teacher training.

Research across different age groups and educational levels demonstrates that mobile learning generally yields positive and powerful effects. Mobile-enhanced science education, particularly across a wide spectrum from primary to higher education, has shown increased achievement and motivation to learn. While mobile learning integration is progressing more rapidly in developed countries, developing countries continue to face digital divides and infrastructure challenges. Despite this, mobile technologies are increasingly being adopted globally as an innovative and effective pedagogical tool for science learning.

In conclusion, the findings in the literature strongly suggest that mobile communication is an approach that enriches the learning experience, increases achievement, and strengthens motivation in science education. It is anticipated that the role of these technologies in education will further expand in the future and that they will be at the center of innovative practices in science learning.

FINDINGS

Academic studies and reports conducted over the last decade reveal that mobile communication technologies offer significant and multidimensional contributions to science education. Research on the use of mobile devices in education demonstrates that these technologies create more flexible, personalized, and interactive learning environments by making learning processes independent of time and space (Kearney et al., 2020; Crompton, 2017). This positively impacts student engagement, motivation to learn, and academic achievement. With the increasing digitalization of science education, mobile technologies have entered the arena where traditional teaching methods are limited. Virtual laboratory applications, augmented reality (AR) technologies, and mobile learning platforms contribute to the development of science process skills by providing students with the opportunity to experiment, observe, and explore conceptual relationships (Zydney & Warner, 2016). These applications help students more easily understand complex science concepts and develop problem-solving skills.

Trends in the literature reveal that mobile learning is becoming an increasingly popular area of research and practice. Especially during the COVID-19 pandemic (2020 and beyond), mobile learning tools have become a core component of distance education and have played a critical role in the sustainability of education systems (Traxler, 2021). This process has demonstrated that mobile technologies can be used not only as supplementary but also as essential educational tools. However, the integration of mobile technologies into science education presents certain challenges. Research emphasizes that factors such as technological infrastructure deficiencies, teachers' digital proficiency levels, quality content production, and students' digital literacy skills directly impact the success of mobile learning (Ertmer & Ottenbreit-Leftwich, 2010). In this context, not only technology-based solutions but also a pedagogically sound and balanced learning design are needed. For mobile-enhanced science education to be effective, blended learning models that holistically blend traditional methods with digital applications are recommended. These models can contribute to increasing students' scientific literacy by combining the accessibility and interactivity advantages of digital technologies with the discovery-based learning processes inherent in science education. In conclusion, a review of the literature published between 2015 and 2025 suggests that the integration of mobile communication technologies into science education has created a new paradigm in education.

Mobile learning paves the way for student-centered, interactive, and enriched learning experiences in science education, and it is anticipated that the use of innovative applications such as augmented reality and virtual laboratories will become widespread. In this context, it is crucial that future studies examine the pedagogical impacts of mobile technologies in greater depth and develop solutions to overcome these limitations. Drawing on this literature, educators and policymakers can take important steps toward creating inclusive and sustainable educational environments that integrate mobile technologies with educational objectives.

CONCLUSION

Studies conducted over the last decade demonstrate that the integration of mobile communication technologies into science education has significantly transformed educational processes. Mobile technologies enable the creation of student-centered, interactive, and personalized learning environments by making learning independent of time and space. Augmented reality, virtual laboratories, and mobile applications, in particular, stand out as effective tools for developing conceptual understanding and scientific process skills in science. However, factors such as infrastructure deficiencies, pedagogical deficiencies, and digital literacy levels must be taken into account in the effective use of these technologies. The literature emphasizes that learning models that blend digital and traditional methods in a balanced way are critical for improving the quality of science education. In this context, it is crucial that educators and policymakers provide the necessary pedagogical support and technological infrastructure to maximize the potential of mobile technologies. Future research should further explore the pedagogical impact of mobile learning on science education and develop solutions to address existing challenges. Thus, mobile communication technologies will contribute to the creation of a sustainable and inclusive learning environment in science education.

RECOMMENDATIONS

• Developing Pedagogical Competencies: In-service training programs should be organized to ensure teachers can use mobile communication technologies effectively and pedagogically meaningfully, and awareness should be raised on digital literacy and technology integration.

• Strengthening Technological Infrastructure: The necessary hardware and internet infrastructure should be improved to ensure the uninterrupted and efficient use of mobile learning applications in educational institutions, and policies should be developed to reduce access inequalities.

• High-Quality and Student-Centered Content Design: Mobile learning materials that are aligned with the science curriculum and include innovative technologies such as interactive and augmented reality should be developed to support student motivation and conceptual understanding.

• Expanding Blended Learning Models: Blended learning models should be expanded by integrating the opportunities offered by mobile technologies with traditional teaching methods, thus enriching learning processes with both digital and face-to-face interactions.

• Digital Literacy and Student Support Programs: Programs that develop digital literacy skills should be implemented to ensure students can use mobile technologies effectively and safely, and awareness-raising efforts should be conducted to address risks such as accessing misinformation and distraction.

• Support and Disseminate Research: Academic research that in-depth examines the pedagogical impact of mobile technologies in science education should be supported, and the findings should be disseminated to inform educational policies and practices.

REFERENCES

Akpınar, Y.(2005). Bilgisayar Destekli Eğitimde Uygulamalar. Ankara: Anı Yayınevi

Bagir, M., Önal Karakoyun, G., & Asiltürk, E., (2022). Views of Science Teachers on the Use of Artificial Intelligence in Education. *İnternational Online Journal Of Educational Sciences, vol.*14, no.5, 1223-1234.

Baldemir, B., & Tutak, T. (2024). Okul Öncesi Öğretmenlerinin Diskalkuliye Yönelik Farkındalık Düzeylerinin Belirlenmesi. *Cumhuriyet Uluslararası Eğitim Dergisi,* 13(4), 847-857. https://doi.org/10.30703/cije.1371417

Bozkurt, A. ve Bozkaya, M.(2013). Etkileşimli e- kitap: Dünü, bugünü ve yarını. Akademik Bilişim 2013, Akdeniz Üniversitesi, Antalya.

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. Computers & Education, 87, 218-237. https://doi.org/10.1016/j.compedu.2015.07.003

Brookings Institution. (2020). Digital divide and education equity in the COVID-19 era. Retrieved from https://www.brookings.edu

Bulduk, Ö. (2024). Fen bilimleri konu öğretimi ve öğrenimi ile ilgili öğretmen ve öğrenci ihtiyaçlarının belirlenmesi: Bir devlet ortaokulu örneği. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi*, 59, 205-239.

Cırık, İ., & Akpolat, T. S. (2024). Abdüktif düşünmenin k12 beceri geliştirme sürecindeki rolü: Matematik dersi Örneği. *Milli Eğitim Dergisi*, *53*(241), 519-542.

Crompton, H. (2017). *Mobile learning: New approach, new theory*. In J. Traxler, B. Mobasher, & S. Kukulska-Hulme (Eds.), **Handbook of mobile learning in contemporary learning contexts** (pp. 9–24). Routledge. https://doi.org/10.4324/9781315669811

Çelik, R., Önal Karakoyun, G., & Asiltürk, E. (2022). Evaluation of middle school 7th grade science skill-based questions according to the revised bloom taxonomy. *International Online Journal Of Educational Sciences, 14*(3), 705-716.

Çetinkaya, M. (2017). Fen eğitiminde modelleme temelinde düzenlenen kişiselleştirilmiş harmanlanmış öğrenme ortamlarının başarıya etkisi. *Ordu Üniversitesi Sosyal Bilimler Araştırmaları Dergisi*, 7(2), 287-296.

Erbek, N., Asiltürk, E., & Kahyaoğlu, M. (2023). Fen Bilimleri Öğretmenlerinin İnovatif Düşünme Becerilerine İlişkin Özyeterlilik Algılarının Çeşitli Değişkenler Açısından İncelenmesi. Fen Bilimleri Öğretimi Dergisi, 11(1), 153-179. https://doi.org/10.56423/fbod.1264434

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education, 42*(3), 255–284. https://doi.org/10.1080/15391523.2010.10782551

Güneş, F. (2022). The direct instruction model. *The Journal of Limitless Education and Research*, *7*(1), 1-39.

Journal of Science Education, 56(4), 315-330. https://doi.org/10.1016/ j.scied.2023.01.001

Kearney, M., Burden, K., & Schuck, S. (2020). Disrupting education using smart mobile pedagogies. *Technology, Pedagogy and Education, 29*(2), 181–193. https://doi.org/10.1080/1475939X.2020.1737566

Klopfer, E., Squire, K., & Jenkins, H. (2002). Environmental Detectives: The development of an augmented reality platform for environmental simulations. Educational Technology Research and Development, 51(1), 87-90.

Mac Callum, K. (2010). Attitudes of educators to the introduction of mobile technology. International Journal of Research in Education Technology, 10(1), 105-120. https://doi.org/10.1080/0000000000

Motiwalla, L. F. (2007). Mobile learning: A framework and evaluation. Computers & Education, 49(3), 581-596. https://doi.org/10.1016/j.compedu.2005.10.011

Nayıroğlu, B., & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Educational Studies*, 11, 65-78. https://doi.org/10.33907/turkjes.1415591

Önal Karakoyun, G. & Asiltürk, E. (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure- Acidity/Basicity Relationship" Topic. *Acta chimica Slovenica*, *68*(3), 645–657.

Önal Karakoyun, G., & Asiltürk, E., (2020). Analysis of Pre-Service Science Teachers' Heuristic Reasoning Processes about Hydrogen Bonding. Journal of Science Learning, vol.4, no.1, 50-60.

Philip, R., & Garcia, P. (2013). Teacher and learner perceptions of mobile learning: A comparative study. Journal of Educational Technology, 12(4), 195-205. https:// doi.org/10.1080/0000000000

Polat, M., & Tutak, T. (2025). Interdisciplinary comparative analysis of science and mathematics teachers' level of technology use in teaching processes, their aims and problems encountered. *International Journal of Research in Teacher Education (IJRTE)*, 16, 34-48. https://doi.org/10.29329/ijrte.2025.1300.03

Süzen, A. B., Tutak, T., İlhan, A., Nayıroğlu, B. (2024). Teacher and Student Opinions on Teaching Four Operations with Integer Numbers in 7th Grade with Counting Stamps. International E-Journal of Educational Studies, 8(17), 142-156. https://doi.org/10.31458/iejes.1343835

Traxler, J. (2021). Learning with mobiles in a pandemic: From emergency remote teaching to resilient education. *Interactive Learning Environments*, 1–13. https://doi.org/10.1080/10494820.2021.1994926

UNESCO. (2018). Guidelines on mobile learning policy. Paris: UNESCO Publishing. Retrieved from https://unesdoc.unesco.org

UNESCO. (2020). Mobile learning for teachers and students: Bridging the digital divide. Retrieved from https://www.unesco.org

Zydney, J. M., & Warner, Z. (2016). Mobile apps for science learning: Review of research. *Computers & Education, 94*, 1–17. https://doi.org/10.1016/j.compedu.2015.11.001

BLENDED LEARNING AND STUDIES ON BLENDED LEARNING IN SCIENCE EDUCATION

Olgu ÇAKAR[1]

Abstract

Blended learning combines classroom and online instruction, enabling the assessment of technology use both inside and outside the classroom, as well as how to reach students more effectively. It can enhance students' success in science education by providing them with a deeper understanding of science topics. This research aimed to examine the role, importance, advantages, and limitations of the blended learning model in science education. It has been demonstrated that the blended learning model holds a significant place in science education by enabling students to learn and understand science topics more effectively.

Keywords: Blended Learning Model, Blended Learning in Science Education, Science Education

Introduction

The current structure of science education faces a number of challenges that limit students' ability to effectively understand and apply science concepts. Traditional classroom lectures can lead to students learning only theoretical concepts and limited hands-on experience (Chuang & Ho, 2015). Digital technologies are widely used in science (Bagır ve ark., 2022; Bulduk, 2024; Çelik et all., 2022; Çetinkaya, 2017; Erbek et all., 2023; Önal Karakoyun et all., 2025; Önal Karakoyun & Asiltürk, 2022; Önal Karakoyun & Asiltürk, 2021) and mathematics (Baldemir ve Tutak, 2024; Cırık ve Akpolat, 2024; Güneş, 2022; Nayıroğlu ve Tutak, 2024; Polat ve Tutak, 2025; Süzen ve ark., 2024) education today. Furthermore, the intensity of classroom instruction can make

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it difficult for students to deeply understand and make connections to science-related topics.

However, the limited number and often expensive nature of laboratory experiences can prevent students from gaining practical experience and learning science concepts hands-on (Stern & Roseman, 2004). Furthermore, the need to accommodate students' different learning styles and paces can make traditional classroom instruction inadequate for every student's needs (Pashler et al., 2008).

These challenges students face in science education can negatively impact their success and effective learning. Therefore, new and innovative approaches must be adopted to provide a more effective learning environment in science education and to foster a deeper understanding of science topics for students. In this context, the role and importance of the blended learning model in science education comes to the fore.

Purpose of the Research

The purpose of this research is to examine the role and importance of the blended learning model in science education. We aim to evaluate the effects of the blended learning model on student achievement, the learning process, and teacher experience in science education. We also aim to understand the potential advantages and challenges of the blended learning model in science education.

What is Blended Learning?

Blended learning is an educational model that combines traditional face-to-face education with online learning methods. This model aims to provide students with a more flexible and effective learning experience. With the rapid development of digital technologies and their increasing use in education, blended learning has gained a significant place in today's education systems. This section will provide a detailed overview of the definition, components, and role of blended learning in education.

Blended learning is an approach that aims to enrich students' learning experiences by combining different teaching strategies and technologies. Staker and Horn (2012) define blended learning as "an educational model in which at least some students maintain some control (in terms of time, place, path, and/or pace) through online learning, and this online learning is conducted in a physical location alongside traditional face-to-face instruction" (Staker & Horn, 2012). This definition emphasizes that blended learning includes both physical and digital components, providing students with a more personalized learning experience.

The blended learning model consists of several components. These components include:

Online Learning Component: Online learning provides students with learning materials and activities accessible through digital platforms. This includes learning management systems (LMS), video lectures, online exams, and interactive learning tools (Graham, 2006).

Face-to-Face Learning Component: Face-to-face learning takes place in a traditional classroom setting, allowing students and teachers to interact directly. This component includes discussions, group work, laboratory activities, and in-class lectures (Picciano, 2009).

Personalized Learning: Blended learning can be adapted to students' individual learning paces and styles. This allows each student to tailor their learning journey to their own needs (Horn & Staker, 2015).

Synchronous and Asynchronous Learning: Blended learning offers both synchronous and asynchronous learning opportunities. Synchronous learning involves live lectures and meetings where students and teachers interact simultaneously online, while asynchronous learning allows students to access learning materials at their own times (Hrastinski, 2008). Blended learning provides flexibility and accessibility in education, making the learning process more dynamic and student-centered. This model provides students with learning opportunities independent of time and place while maintaining the importance of face-to-face interactions. Effective implementation of blended learning can increase students' academic success and equip them with 21st-century skills (Garrison & Vaughan, 2008).

As a result, blended learning is considered a significant innovation in modern education systems. It enhances learning experiences through the integration of technology while also supporting and improving traditional educational methods. Effective implementation of this model has significant potential to improve quality in education (Means et al., 2010).

The Importance of Blended Learning in Science Education

Blended learning has great potential in the context of science education, allowing students to understand scientific concepts, develop critical thinking skills, and actively participate in scientific processes. Because science education requires both theoretical knowledge and practical applications, blended learning offers significant advantages by offering flexibility and variety to meet these requirements (Garrison & Vaughan, 2008).

The importance of blended learning in science education stems primarily from its support for a student-centered learning approach. Blended learning models allow students to manage and personalize their own learning. This allows them to learn at their own pace, review topics they don't understand, and conduct in-depth research in areas of interest (Horn & Staker, 2015). Having students access online resources repeatedly is a significant advantage, particularly when understanding complex scientific concepts (Means et al., 2010).

Science education becomes more effective when it is enriched with practical applications such as laboratory work and experiments. Blended learning enables these practices to be supplemented with online environments. For example, virtual laboratories and simulations offer students the opportunity to conduct experiments that may not be possible in physical laboratories. This not only reduces costs but also enriches students' learning processes through diverse experiences (Graham, 2006).

Blended learning provides flexibility and accessibility in science education. Students can access learning materials independently of the physical classroom environment, without any time or space constraints. This is a significant advantage, especially in distance learning and for students who cannot attend school regularly for various reasons (Means et al., 2010). Furthermore, digital learning tools support the full participation of students with disabilities in the educational process (Graham, 2006).

Blended learning enables more effective assessment of learning processes in science education. Online platforms offer extensive data collection capabilities to track student progress and assess performance. This helps teachers identify student strengths and weaknesses and adjust instructional strategies accordingly (Garrison & Vaughan, 2008). Thus, continuous feedback and self-assessment encourage more active student engagement in learning (Horn & Staker, 2015).

The importance of blended learning in science education stems from its numerous advantages, including student-centered learning, practical and experiential learning, the development of critical thinking and problem-solving skills, flexibility and accessibility, and the ability to assess learning processes. This model is a powerful tool for improving the quality of science education and equipping students with 21st-century skills (Graham, 2006; Means et al., 2010).

Blended Learning Strategies in Science Education

Science education aims to help students acquire scientific knowledge and skills, develop critical thinking skills, and understand scientific processes.

Blended learning strategies offer effective tools for achieving these goals. Blended learning combines traditional classroom activities with online learning, providing students with more flexible and interactive learning environments. This section will examine blended learning strategies that can be used in science education.

The flipped classroom strategy is one of the most widely used methods of blended learning. In this strategy, students learn course materials online at home, and class time is used more for practice, discussion, and experiments. In science education, the flipped classroom model offers more time for laboratory work, group projects, and scientific discussions (Bergmann & Sams, 2012). For example, students can learn concepts by watching video lectures at home and conduct experiments in class under teacher guidance.

A problem-based learning strategy encourages students to apply scientific knowledge by working on real-world problems. This strategy combines online and face-to-face interactions in a blended learning environment. Students conduct research and gather information online and develop solutions by discussing this information in classroom sessions (Savery, 2006). In science education, PBL helps students develop scientific inquiry skills and encourages them to think like scientists.

Simulations and virtual laboratories facilitate the understanding of complex concepts and experiments in science education. Online simulations allow students to virtually perform experiments they might encounter in a real laboratory setting. This strategy is particularly effective in situations where experiments can be costly or dangerous (De Jong et al., 2013). Students can experience scientific processes through simulations and reinforce these experiences through classroom discussions.

A cooperative learning strategy encourages students to learn through group work and collaborative projects. In blended learning environments, cooperative learning is supported by online and face-to-face interactions. Students communicate with group members on online platforms to develop project plans and conduct data analysis (Johnson & Johnson, 2009). In science education, cooperative learning helps students develop scientific communication skills and teamwork abilities.

Learning management systems enable the effective implementation of blended learning strategies. LMSs provide students with access to course materials, assignment submission, online discussion forums, and assessment. In science education, LMSs provide students with easy access to a variety of resources, including scientific articles, video lectures, and interactive activities

(Watson & Watson, 2007). These systems also significantly simplify teacher monitoring of student progress and providing feedback.

A personalized learning strategy offers customized instruction tailored to students' individual needs and learning pace. In blended learning environments, personalized learning is supported by digital tools and adaptive learning systems. Students can create their own learning roadmaps on online platforms and receive individual guidance from teachers (Pane et al., 2015). In science education, this strategy helps students better understand scientific concepts and manage their own learning processes.

Blended learning strategies in science education support students' acquisition of scientific knowledge and skills, development of critical thinking skills, and understanding of scientific processes. Strategies such as the flipped classroom, problem-based learning, simulations and virtual laboratories, collaborative learning, learning management systems, and personalized learning offer innovative and effective teaching methods in science education. These strategies provide students with flexible and enriched learning experiences, preparing them for the scientific and technological world of the 21st century (Bergmann & Sams, 2012; Graham, 2006).

CONCLUSION

This research aimed to examine the role, importance, advantages, and limitations of the blended learning model in science education. The results of the research are summarized as follows:

Blended learning in science education transcends the limitations of traditional classroom lessons, providing students with a more effective, interactive, and personalized learning experience. It can enhance students' success in science education by providing a deeper understanding of science topics. It also increases student motivation and interest, accommodates diverse learning styles and paces, and enriches the science learning experience.

The potential of the blended learning model in science education is significant. Factors such as the development of digital technology, flexible learning models, the transfer of laboratory experiences to virtual environments, the strengthening of student-centered approaches, and teacher training and development support the effective implementation of the blended learning model. However, the limitations of the research should also be considered.

Conclusively, it is concluded that the blended learning model holds an important place in science education by enabling students to learn and understand science subjects more effectively. In the future, further expansion and development of the blended learning model in science education can enhance science students' scientific thinking skills and science-related competencies.

The results of the study make a significant contribution to understanding the impact of the blended learning model in science education and contributing to its practical applications.

REFERENCES

Bagir, M., Önal Karakoyun, G., & Asiltürk, E., (2022). Views of Science Teachers on the Use of Artificial Intelligence in Education. *International Online Journal Of Educational Sciences* , vol.14, no.5, 1223-1234.

Baldemir, B., & Tutak, T. (2024). Okul Öncesi Öğretmenlerinin Diskalkuliye Yönelik Farkındalık Düzeylerinin Belirlenmesi. *Cumhuriyet Uluslararası Eğitim Dergisi,* 13(4), 847-857. https://doi.org/10.30703/cije.1371417

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International Society for Technology in Education.

Bulduk, Ö. (2024). Fen bilimleri konu öğretimi ve öğrenimi ile ilgili öğretmen ve öğrenci ihtiyaçlarının belirlenmesi: Bir devlet ortaokulu örneği. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi*, 59, 205-239.

Chuang, K.-Y., & Ho, Y.-S. (2015). An evaluation based on highly cited publications in Taiwan. *Current Science, 108*(5), 933–941.

Cırık, İ., & Akpolat, T. S. (2024). Abdüktif düşünmenin k12 beceri geliştirme sürecindeki rolü: Matematik dersi Örneği. *Milli Eğitim Dergisi*, *53*(241), 519-542.

Çelik, R., Önal Karakoyun, G., & Asiltürk, E. (2022). Evaluation of middle school 7th grade science skill-based questions according to the revised bloom taxonomy. *International Online Journal Of Educational Sciences* , 14(3), 705-716.

Çetinkaya, M. (2017). Fen eğitiminde modelleme temelinde düzenlenen kişiselleştirilmiş harmanlanmış öğrenme ortamlarının başarıya etkisi. *Ordu Üniversitesi Sosyal Bilimler Araştırmaları Dergisi*, 7(2), 287-296.

Erbek, N., Asiltürk, E., & Kahyaoğlu, M. (2023). Fen Bilimleri Öğretmenlerinin İnovatif Düşünme Becerilerine İlişkin Özyeterlilik Algılarının Çeşitli Değişkenler Açısından İncelenmesi. Fen Bilimleri Öğretimi Dergisi, 11(1), 153-179. https://doi.org/10.56423/fbod.1264434

Garrison, D. R., & Vaughan, N. D. (2008). *Blended learning in higher education: Framework, principles, and guidelines*. John Wiley & Sons.

Graham, C. R. (2006). Blended learning systems. In C. J. Bonk & C. R. Graham (Eds.), *The handbook of blended learning: Global perspectives, local designs* (pp. 3-21). San Francisco, CA: Pfeiffer Publishing.

Güneş, F. (2022). The direct instruction model. *The Journal of Limitless Education and Research*, *7*(1), 1-39.

Horn, M. B., & Staker, H. (2015). *Blended: Using disruptive innovation to improve schools*. John Wiley & Sons.

Hrastinski, S. (2008). Asynchronous and synchronous e-learning. *Educause Quarterly*, 31(4), 51-55.

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365–379.

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2010). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*. U.S. Department of Education.

Nayıroğlu, B., & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Educational Studies*, 11, 65-78. https://doi.org/10.33907/turkjes.1415591

Önal Karakoyun, G. & Asiltürk, E. (2021). The Role of Heuristics in the Reasoning Process of Pre-Service Science Teachers on the "Chemical Structure- Acidity/Basicity Relationship" Topic. *Acta chimica Slovenica*, *68*(3), 645–657.

Önal Karakoyun, G., & Asiltürk, E., (2020). Analysis of Pre-Service Science Teachers' Heuristic Reasoning Processes about Hydrogen Bonding. Journal of Science Learning, vol.4, no.1, 50-60.

Pane, J. F., Steiner, E. D., Baird, M. D., Hamilton, L. S., & Pane, J. D. (2015). *Continued progress: Promising evidence on personalized learning* (Research Report No. RR-1365-RC). RAND Corporation. https://www.rand.org/pubs/research_reports/RR1365.html

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). *Learning styles: Concepts and evidence*. Psychological Science in the Public Interest, 9(3), 105–119. https://doi.org/10.1111/j.1539-6053.2009.01038.x.

Picciano, A. G. (2009). Blending with purpose: The multimodal model. *Journal of Asynchronous Learning Networks*, 13(1), 7-18.

Polat, M., & Tutak, T. (2025). Interdisciplinary comparative analysis of science and mathematics teachers' level of technology use in teaching processes, their aims and problems encountered. *International Journal of Research in Teacher Education (IJRTE)*, 16, 34-48. https://doi.org/10.29329/ijrte.2025.1300.03

Savery, J. R. (2006). Overview of Problem-Based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1, 9-20.

Staker, H., & Horn, M. B. (2012). *Classifying K-12 blended learning*. Innosight Institute.

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching, 41*(6), 538–568. https://doi.org/10.1002/tea.20019

Süzen, A. B., Tutak, T., İlhan, A., Nayıroğlu, B. (2024). Teacher and Student Opinions on Teaching Four Operations with Integer Numbers in 7th Grade with Counting Stamps. International E-Journal of Educational Studies, 8(17), 142-156. https://doi.org/10.31458/iejes.1343835

Watson, W. R., & Watson, S. L. (2007). An argument for clarity: What are learning management systems, what are they not, and what should they become? *TechTrends, 51*(2), 28–34. https://doi.org/10.1007/s11528-007-0023-y.

Zhu, Z., Bi, J., Pan, Y., Ganguly, S., Anav, A., Xu, L., Samanta, A., Piao, S., Nemani, R. R., & Myneni, R. B. (2013). Spatial relationship between climatologies and changes in global vegetation activity. *Remote Sensing of Environment, 133*, 403–415. https://doi.org/10.1016/j.rse.2013.02.009.

SCIENCE TEACHER CANDIDATES' THOUGHTS ON THE AGS EXAM

Erol ASİLTÜRK[1]

Abstract

The purpose of this study is to examine prospective science teachers' opinions about the AGS exam. Therefore, the study employed an interview method. Interviews are a qualitative research technique that generally involves engaging in conversations with participants and asking open-ended questions to collect data on a topic. The sample for this study consisted of prospective science teachers studying at a university in eastern Turkey. The sample consisted of 20 students, 10 males and 10 females, who volunteered. A structured interview form, developed by the researcher, was used as the data collection tool in this study. After the interview form was prepared by the researcher, it was presented to three academics who are experts in their field. Necessary corrections were made based on the feedback received, and the form was finalized. The analysis of the study was conducted using content analysis. Content analysis can be defined as the process of quantifying and digitizing what people write and say. This method is based on categorizing what is written and spoken and investigating how frequently it is used (Simon, Burstein, 1985). The study concluded that prospective teachers had heard about the upcoming AGS exam, but lacked sufficient information about it, and because it was their first time taking it, they were experiencing anxiety and apprehension. It was determined that they wanted the exam's content to encompass the courses they had taken at their faculty and the courses taught in their schools.

Keywords: Science, Prospective Teacher, AGS Exam

Introduction

Becoming a science teacher typically requires completing a teacher education program and passing an examination to demonstrate subject knowledge and

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teaching skills. Research shows that many pre-service science teachers enter these programs with deficiencies in their understanding of core science concepts, often stemming from traditional, didactic teaching methods in their training. However, conceptual and inquiry-based approaches can significantly improve content knowledge and teaching skills (Stoddart et al., 1993; Akcanca, 2020; Supeno et al., 2022). Studies also reveal that while pre-service science teachers typically possess moderate to high levels of computational thinking and science learning skills, their scientific literacy can lag behind, and misconceptions about scientific concepts remain common (Hasnawati et al., 2022; Uyanık, 2025; Elbahan et al., 2023). Prospective teachers tend to prefer traditional teaching styles, but exposure to exploratory and inquiry-based methods can change their perspectives and improve their skills in planning and delivering effective science lessons (Küçükaydın et al, 2020; Akcanca, 2020). Practical experiences, such as lesson study and video analysis of classroom instruction, help candidates reflect on and refine their teaching strategies, particularly when focusing on student thinking and challenging teaching frameworks (Johnson, 2019; Supeno et al., 2022). Additionally, developing technological, pedagogical, and content knowledge (TPACK) is crucial, and opportunities for self-assessment during training can help candidates address gaps before entering the profession (Keçeci, 2017). Generally, effective teacher preparation programs combine strong content knowledge, modern pedagogical approaches, and practical teaching experiences to ensure candidates are prepared for certification exams and classroom success (Stoddart et al., 1993; Akcanca, 2020; Supeno et al., 2022). Science teacher candidates were required to take the KPSS exam after graduating from university and achieve a certain score to be appointed as teachers. Recent regulations have made changes to the steps required for becoming teachers. The Ministry of National Education has established Education Academies. Now, science teacher candidates will be required to take the AGS exam after graduation. A number of teacher candidates, equal to the number of quotas announced for teacher appointment, will receive fourteen months of training at the academy and take exams during this training. Those who pass the exams throughout the training will be appointed as teachers and begin their work. Therefore, this study was conducted to gather the opinions of science teacher candidates about the upcoming AGS exam.

Purpose of the Study

The purpose of this study is to examine the opinions of prospective science teachers regarding the AGS exam.

Study Method

Interviews were used in this study. Interviews are a qualitative research technique that typically involves engaging in conversations with participants and asking open-ended questions to collect data on a topic. In most cases, the interviewer is a subject matter expert who aims to understand the participants' opinions through a series of well-planned and implemented questions (URL 1).

Study Sample

The sample for this study consisted of prospective science teachers studying at a university in eastern Turkey. The sample consisted of 20 students, 10 males and 10 females, who were selected on a voluntary basis. In this study, a structured interview form, developed by the researcher, was used as the data collection tool. After the interview form was prepared by the researcher, it was presented to three academics who are experts in the field. Necessary corrections were made based on the feedback received, and the form was finalized.

Data Analysis

The study was analyzed using content analysis. Content analysis can be described as the process of quantifying and digitizing what people write and say. The basis of this method is the categorization of what is written and said and the investigation of how frequently it is used (Simon, Burstein, 1985).

Findings

This study aimed to examine the opinions of prospective science teachers regarding the AGS exam. For this purpose, prospective science teachers studying at a university in eastern Turkey were selected as the sample. An interview form developed by the researcher was administered to these prospective teachers. The questions asked and the responses received during the interviews with the prospective teachers are presented below.

Q1. Have you heard of the AGS exam?

The answers to Question 1 are listed below.

S1. I heard about the AGS exam.

S2. I heard about it too.

S3. Yes, I heard about it.

S4. No, I heard about it.

S5. I heard about the AGS exam.

S6. I heard about it too.

S7. Yes, I heard about it too.

S8. I heard about it.

S9. I heard about the exam.

S10. I heard about it too.

S11. I heard about it.

S12. Oh, I heard.

S13. I heard about the upcoming exam.

S14. I heard about the exam.

S15. Yes, I heard about this exam.

S16. I heard.

S17. Oh, I heard about the exam.

S18. I heard about it too.

S19. Yes, I heard about it.

S20. I heard about the AGS exam.

Q2. What are your thoughts on the AGS exam?

The answers to Question 2 are provided below.

S1. I always worry about new exams.

S2. This will be the first time the AGS exam has been held. I've heard something about the exam, but I don't know exactly how it will be conducted. That's why I'm nervous.

S3. The exam is new, so I don't know.

S4. We've heard some information. We're trying to study accordingly.

S5. I'm confused.

S6. I need more information.

S7. It would have been better if this first exam hadn't hit me.

S8. First exams are usually full of unknowns.

S9. I'm studying based on the instructions given.

S10. I can't say I've studied very hard.

S11. I think it will be difficult.

S12. Taking this exam for the first time scares me.

S13. I'm studying, but I don't have much hope.

S14. I'm studying, but I don't know what to expect on the exam.

S15. I'm worried because it's my first time.

S16. I'm so confused.

S17. It's going to be a new exam this year. I don't know what to think.

S18. The AGS exam. I'm trying to do my best.

S19. I'm worried because it's going to be a new exam.

S20. I'm worried because I haven't fully mastered the content.

Q3. Do you find the upcoming AGS exam positive?

The answers to question 3 are listed below.

S1. The exam is going to be a new exam. Therefore, I'm undecided.

S2. Frankly, I'm not thinking much about it.

S3. I don't think it's very positive.

S4. I don't find it positive because it's a new exam.

S5. Frankly, it's a new exam. I don't know its content exactly. That's why I don't find it very positive.

S6. I don't think it's very positive.

S7. This exam will be administered recently. Therefore, I'm confused. I don't know exactly what it is. That's why I'm not very positive.

S8. No comments because I'm confused.

S9. I don't find it positive because I don't fully understand its content.

S10. I don't agree.

S11. I'm undecided because I don't know what will change compared to previous exams.

S12. I just heard about this exam. It's the first time it's been held. I'm nervous because it's the first time. I'm quite worried.

S13. I'm worried and anxious.

S14. The AGS exam will be held again this year. I've heard something about its content. However, I'm nervous because it's the first time it's been held.

S15. I can't say I have a very positive opinion.

S16. People are usually nervous about the first exam. I'm also worried because this exam is new. I can't predict for sure whether I'll pass or not.

S17. I've been studying for the exam from what I've heard, but I don't have a very positive opinion.

S18. I'm undecided.

S19. I've heard some things about the content of the new AGS exam. I'm studying based on these rumors. However, I'm anxious and worried.

S20. I'm studying, we'll see.

Q4. What would you like the content of the upcoming AGS exam to consist of?

The answers to question 4 are listed below.

S1. I would like each teacher to prepare according to their own field.

S2. I would like the content of the exam to be related to my field.

S3. The AGS exam will be held this year. I would like the content of this exam to be exactly what I would cover in the classes I would teach if I were appointed.

S4. I would like it to be related to my field.

S5. I would like the content of the AGS exam to consist of the courses I took at the faculty. I would also like it to cover the courses I will teach as a teacher.

S6. I would like it to be in line with the objectives of the Ministry of National Education.

S7. I'm undecided.

S8. I would like the content of the AGS exam to be prepared by taking into consideration the fields of study of each candidate taking this exam.

S9. No comments.

S10. I would like it to be related to my field.

S11. Until now, all candidates from every field took the exams. I would like the exams to be tailored to the candidates' fields of study. For example, I wouldn't want to take the same exam as a prospective art teacher and be evaluated accordingly.

S12. I would like to take the exam that will only cover my field.

S13. I would like it to be related to my field and not include other courses.

S14. I would like it to be related to the objectives.

S15. I would like the content of the AGS exam to be tailored to the courses I will teach in schools when I am appointed.

S16. I would like the exam to consist of the courses I have taken at the faculty.

S17. I would like the content of the AGS exam to be prepared in line with the objectives of the Ministry of National Education taught in schools.

S18. I would like to take an exam designed exclusively for prospective science teachers.

S19. Undecided.

S20. I would like to take an exam specifically designed for my field.

Conclusion

This study aimed to examine the opinions of prospective science teachers regarding the AGS exam. For this purpose, prospective science teachers studying at a university in eastern Turkey were selected as a sample. An interview form developed by the researcher was administered to these prospective teachers. The questions asked in the interview form and the responses received are presented under the findings section.

Prospective teachers stated that they had heard about this year's AGS exam. However, they also stated that they had some knowledge about the exam's content. While they reported learning some information about it, they still felt they weren't fully informed about its content. Naturally, this thought rightfully leads them to anxiety and worry. It's almost impossible to say that the prospective teachers interviewed have positive thoughts about the upcoming AGS exam. Because they are anxious and worried about this exam, they don't hold very positive views about it. Furthermore, prospective teachers were asked what they wanted the AGS exam to consist of. In response, some of the prospective teachers said they wanted it to consist of courses they had taken at their faculty. Some stated that they wanted the exam to consist of the same learning outcomes they would teach in schools when they became teachers. Others said they wanted an exam structure that combined these two elements. On the other hand, some prospective teachers expressed their belief that teachers in all fields should take separate exams for each field, rather than the same exams as previously administered. For example, some prospective teachers believe it would be inappropriate to take the same exam with a candidate who graduated from an art department. Others believe it would be more beneficial for prospective teachers to take exams tailored to their specific fields.

Recommendations

It could be suggested that the content of the AGS exam cover the courses prospective teachers take at their faculties. Furthermore, the content of the exam could also cover the courses taught at schools. Prospective teachers could be asked to take separate exams based on their fields. This study was conducted with prospective science teachers. Therefore, this study could be conducted with prospective teachers in other fields, and the results could be discussed.

References

Akcanca, N. (2020). Teacher Candidates' Perspectives about Applied 'Basic Science in Primary Education' Course, *Educational Policy Analysis and Strategic Research*, 2020, Vol. 15(2) 7-24.

Elbahan, H., Elbahan, M. H., & Balbağ, M. Z. (2023). Determining the level of computational thinking skills of science teacher candidates. *Osmangazi Journal of Educational Research*, 10(Special Issue), 254-272.

Hasnawati, H., Syazali, M., & Widodo, A. (2022). Analysis of Understanding Science Concepts for Prospektüse Elementary School Teacher Candidates. *Jurnal Penelitian Pendidikan IPA*, 8(6), 2954–2960.

Keçeci, G., Zengin, F. K. (2017). Observing the technological pedagogical and content knowledge levels of science teacher candidates. *Educational Research and Reviews*. Vol. 12(24), pp. 1178-1187.

Küçükaydın, M. A., and Gökbulut, Y. (2020). Beliefs of Teacher Candidates Toward Science Teaching. *Journal of Scıence Teacher Educatıon*, Vol. 31, No. 2, 134–150 https://doi.org/10.1080/1046560X.2019.1673603.

Johnson, J. H., & and Mawyer, K. N. (2019). Teacher Candidate Tool-Supported Video Analysis of Students'Science Thinking. *Journal of Scıence Teacher Educatıon*, Vol. 30, No. 5, 528–547 https://doi.org/10.1080/1046560X.2019.1588630.

Simon, J., Burstein, P. (1985). *Basic Research Methods in Social Sciences*, NewYork: Random Press.

Stoddart, T., Connell, M., Stofflett, R., & Peck, D. (1993). Reconstructing elementary teacher candidates' understanding of mathematics and science content, *Teaching and Teacher Education*, Volume 9, Issue 3, June 1993, Pages 229-241.

Supeno, S., Prihandono, T., Mahardika, I. K., Sudarti, S., & Nuraini, L. (2022). Improving The Instructional Abilities of Science Teacher Candidates Through Lesson Study. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2778–2784. https://doi.org/10.29303/jppipa.v8i6.2595

URL 1. https://www.questionpro.com/blog/tr/arastirma-ve-yontemlerde-mulakat-turleri/#:~:text=M%C3%BClakat%2C%20genellikle%20kat%C4%B1l%C4%B1mc%C4%B1larla%20sohbet%20etmek,sorular%20ve%20cevaplar. Retrieved from the address on 14.04.2025.

Uyanık, G. (2025). The relationship between science learning skills and science literacy levels of classroom teacher candidates. *Journal of Computer and Education Research*, 13 (25), 374-387. https://doi.org/10.18009/jcer.1602649.

SCIENCE TEACHER CANDIDATES' OPINIONS ABOUT BECOMING TEACHERS

Erol ASİLTÜRK[1]

Abstract

The purpose of this study is to examine the views of prospective science teachers regarding their potential appointment as teachers after graduation. The study was conducted using the interview method, a qualitative research method. Interviews are a technique consisting of open-ended questions that aim to obtain in-depth data on a specific topic through one-on-one conversations with participants. The research sample consisted of prospective science teachers studying at a university in eastern Turkey. The sample consisted of 20 students, 10 males and 10 females, who volunteered. A structured interview form developed by the researcher was used as the data collection tool. Following the preparation of the form, the opinions of three academics who are experts in their fields were obtained, and the necessary adjustments were made accordingly to form the final form. The data obtained was evaluated using content analysis. Content analysis is the process of systematically categorizing individuals' written or spoken statements and determining the frequencies of these categories (Simon & Burstein, 1985). According to the research findings, prospective teachers stated that changes had been made to the system during the teacher appointment process and that a new exam called the AGS would now replace the KPSS. However, they expressed insufficient knowledge about the exam and expressed anxiety and uncertainty due to its being the first time it was administered. This suggests that prospective teachers' views on appointment to the profession are generally negative.

Keywords: Science, Teacher Candidate, Teaching

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Introduction

Pre-service science teachers' thoughts about becoming a teacher are shaped by their perspectives on the teaching profession, teaching approaches, perceptions of professional competence, and preparation processes. Generally, pre-service science teachers have a positive outlook on teaching, but they experience various challenges in the implementation and planning processes.

Teaching Approaches and Perceptions of Professional Competence

The majority of pre-service science teachers embrace a more traditional teaching style. These candidates tend to prefer teacher-centered methods in their courses, with male candidates showing a higher tendency towards this (Küçükaydın, Gökbulut, 2020).

Practical courses and microteaching techniques help pre-service science teachers assess and develop their own teaching competence. Such practices increase their integration of technology, pedagogical knowledge, and content knowledge (Keçeci, Zengin, 2017; Supeno et al., 2022).

Reflections and Challenges Regarding the Teaching Process

Candidates who have gained awareness of inquiry-based teaching approaches report difficulties in the lesson planning and implementation stages. It is emphasized that practice-based training should be increased beyond theoretical knowledge (Akcanca, 20020).

Candidates are making progress in deeply understanding students' ideas and developing teaching strategies appropriate to these ideas. However, they often tend to evaluate students' ideas as right or wrong (Johnson, & Mawyer, 2019; Gotwals, & Birmingham, 2015). Factors influencing preservice science teachers' perspectives on teaching are presented in Table 1 below.

Table 1. Factors Influencing Preservice Science Teachers' Perspectives on Teaching

Factor	Effect
Tendency towards traditional teaching styles	A teacher-centered approach is dominant.
Practical training and self-assessment	Increased professional competence and self-confidence.
Awareness of inquiry-based teaching	Difficulty in planning and implementation, need for development.
Approach to student thinking	Trend towards superficial (right or wrong) evaluation.

Prospective Teachers' Tendencies Towards Teaching Approaches: An Assessment

This study analyzed prospective teachers' attitudes toward the teaching process and their impact on their professional development based on four key factors. These factors were addressed within the framework of teaching approach, practical experiences, awareness of inquiry-based teaching, and attitudes toward student thinking.

1. Tendency to Traditional Teaching Style

A significant portion of the participants still lean toward traditional, teacher-centered approaches to teaching. In this approach, the teacher acts as a transmitter of knowledge, while the student assumes a more passive receiver role. This can be interpreted as a reflection of prospective teachers' desire to control the teaching process and the influence of the current educational culture. This tendency needs to be transformed to ensure a transition to contemporary teaching approaches that are student-centered and based on active participation.

2. Applied Training and Self-Assessment

Applied teaching activities and self-assessment processes significantly increase teacher candidates' perceptions of professional competence and self-confidence. Candidates who have the opportunity to be personally involved in the teaching process and evaluate their own performance exhibit more positive attitudes toward developing their professional identity. This finding demonstrates the critical importance of applying theoretical knowledge in the field and implementing structured feedback processes for teacher preparation programs.

3. Awareness of Inquiry-Based Teaching

While prospective teachers are aware of the importance of inquiry-based teaching in education, they express various challenges in the planning and classroom implementation of this approach. This suggests that while prospective teachers possess theoretical knowledge, they lack sufficient experience in translating this knowledge into effective teaching strategies. Therefore, curriculum programs should include more comprehensive educational content focused on inquiry thinking and the practical aspects of this approach.

4. Approach to Student Thinking

Participants' approach to student responses and ideas was largely dominated by a superficial, right-or-wrong evaluation tendency. This approach demonstrates a lack of in-depth analysis of student thinking and suggests that pedagogical assessment skills need development. Therefore, fostering preservice teachers' ability to assess student thinking from a constructivist perspective should be a priority goal of teacher education programs.

Purpose of the Study

The purpose of this study is to examine the views of prospective science teachers regarding their ability to be appointed as teachers after graduation.

Study Method

This study used the interview method, a qualitative research method. Interviews are a technique that typically involves collecting data through open-ended questions and aims to gain an in-depth understanding of individuals' opinions. In most cases, the interviewer is a subject matter expert who aims to elicit participants' opinions through a well-planned and systematic set of questions (URL 1).

Study Sample

The study sample consisted of prospective science teachers studying at a university in eastern Türkiye. The sample consisted of 20 students, 10 males and 10 females, selected on a voluntary basis.

Data Collection Tools

A structured interview form developed by the researcher was used as the data collection tool. Following the preparation of the form, the opinions of three academic experts in the field were obtained, and necessary revisions were made based on these opinions before the form was finalized.

Data Analysis

The collected data was evaluated using content analysis. Content analysis is a method based on categorizing individuals' written or spoken statements and examining the frequency with which these categories occur. The primary goal of this method is to systematically and meaningfully classify the data and achieve meaningful results (Simon & Burstein, 1985).

Findings

This study aimed to examine the views of prospective science teachers regarding their potential employment as teachers upon graduation. For this purpose, prospective science teachers studying at a university in eastern Turkey were selected as a sample. An interview form developed by the researcher was administered to these prospective teachers. Some of the questions asked and the responses received during the interviews are listed below.

Q1. Have you heard of the AGS exam?

The answers to Question 1 are provided below.

S1. I've heard of the AGS exam.

S2. I've heard of it too.

S3. Yes, I've heard of it.

S4. No, I've heard of it.

S5. I've heard of the AGS exam.

S6. I've heard of it too.

S7. Yes, I've heard of it too.

S8. I've heard of it.

S9. I heard about the exam.

S10. I heard about it too.

S11. I heard about it.

S12. Oh, I heard about it.

S13. I heard about the upcoming exam.

S14. I heard about the exam.

S15. Yes, I heard about this exam.

S16. I heard about it.

S17. Oh, I heard about the exam.

S18. I heard about it too.

S19. Yes, I heard about it.

S20. I heard about the AGS exam.

Q2. What are your thoughts on the AGS exam?

The answers to Question 2 are provided below.

S1. I always worry about new exams.

S2. This will be the first time I've taken the AGS exam. I've heard about it, but I don't know exactly how it will be administered. That's why I'm nervous.

S3. The exam is new, so I don't know.

S4. We've heard some information. We're trying to study accordingly.

S5. I'm confused.

S6. I need more information.

S7. It would have been better if this first exam hadn't hit me.

S8. First exams are usually full of unknowns.

S9. I'm studying according to the instructions given.

S10. I can't say I've studied very hard.

S11. I think it will be difficult.

S12. Taking this exam for the first time scares me.

S13. I'm studying, but I don't have much hope.

S14. I'm studying, but I don't know what to expect on the exam.

S15. I'm worried because it's my first time.

S16. I'm so confused.

S17. It's going to be a new exam this year. I don't know what to think.

S18. The AGS exam. I'm trying to do my best.

S19. I'm worried because it's going to be a new exam.

S20. I'm worried because I haven't fully mastered the content.

Q3. Do you find the upcoming AGS exam positive?

The answers to Question 3 are listed below.

S1. The exam will be new. Therefore, I'm undecided.

S2. Frankly, I don't think much of it.

S3. I'm not very positive about it.

S4. I don't find it positive because it's a new exam.

S5. Frankly, it's a new exam. I don't know the exact content. Therefore, I don't find it very positive.

S6. I don't find it very positive.

S7. This exam will be administered newly. Therefore, I'm confused. I don't know exactly what it is. That's why I'm not very positive.

S8. No comments because I'm confused.

S9. I don't find it positive because I haven't fully grasped the content.

S10. I don't agree.

S11. I'm undecided because I don't know what will change compared to previous exams.

S12. I just heard about this exam. It's the first time it's been administered. I'm nervous because it's the first time it's been administered. I'm quite worried.

S13. I'm worried and anxious.

S14. The AGS exam will be held this year. I've heard some things about its content. However, I'm worried because it's the first time it's been held.

S15. I can't say I have a very positive outlook.

S16. People are usually anxious about their first exam. I'm also worried because this exam is a new one. I can't say for sure whether I'll pass or not.

S17. From what I've heard, I'm studying for the exam, but I don't think it's very positive.

S18. I'm undecided.

S19. I've heard some things about the content of this new AGS exam. I'm studying based on these rumors. However, I'm anxious and worried.

S20. I'm studying, we'll see.

Q4. What are your thoughts on being appointed as a teacher?

The answers to Question 4 are provided below.

S1. I don't think I'll be appointed.

S2. I'll work as hard as I can, but I don't have much hope.

S3. The AGS exam will be held again this year. I don't know the exact content of this exam. This has a negative impact on me.

S4. Generally, we're all feeling down.

S5. If the AGS exam consists of courses I've taken at the faculty, my chances of passing the exam and being appointed will increase.

S6. I will do my best to be appointed.

S7. I'm even undecided about taking the exam.

S8. Since our appointment depends on the AGS exam, which will be held for the first time this year, I would like the exam content to be prepared considering the fields of study of each candidate taking this exam.

S9. No comment.

S10. If the exam is truly related to my field, my chances of being appointed will increase.

S11. Until now, all candidates from all fields were taking the exams. I would like to see exams tailored to each candidate's field of study. For example, I wouldn't want to take the same exam as a prospective art teacher and be evaluated accordingly.

S12. I would like to take the exam only in my field so I can be appointed.

S13. I don't think so.

S14. If the AGS exam, which will be held for the first time this year, is focused on achievements, I think my chances of passing the exam and being appointed will increase.

S15. I would like the content of the AGS exam to be tailored to the courses I will teach at school once I am appointed. This would make it easier for me to be appointed and would be beneficial for my future career.

S16. After the announcements, I don't have a very positive outlook on being appointed.

S17. The AGS exam will be held for the first time this year, and since I don't have enough information about it, I don't believe I can be appointed.

S18. If there were an exam only for science teacher candidates, I would consider being appointed.

S19. I'm undecided.

S20. Like many of my friends, I don't think I can be appointed.

Conclusion

This study aimed to examine the views of prospective science teachers regarding being appointed as teachers after graduating from a faculty. For this purpose, prospective science teachers studying at a university in eastern Turkey were selected as a sample. An interview form developed by the researcher was administered to these prospective teachers. The questions asked in the interview form and the responses received are presented under the findings section.

Prospective science teachers stated that the number of teachers appointed in their fields is insufficient and, therefore, they are not optimistic about their future appointments. Furthermore, the Ministry of National Education has implemented a significant change in the teacher appointment system as of 2025. The Public Personnel Selection Examination (KPSS), which had been implemented in previous years, has been abolished, replaced by the "Teacher

Academy" and a new examination system called the "Academic Development Examination (AGS).

Under the new system, prospective teachers are required to take the AGS exam after completing their undergraduate education and secure a place within the designated quota. Candidates who qualify for this quota will undergo a fourteen-month professional development training program, undergo various assessments during this period, and, if successful, may be appointed as teachers. This system, implemented for the first time in Turkey, has also brought uncertainty and anxiety for prospective teachers.

In this context, this study examined the perceptions and attitudes of prospective teachers regarding the new exam system through interviews. The majority of prospective teachers stated that they were aware of the AGS exam but lacked sufficient and clear information about its content. The limited information available about the exam content increases the sense of uncertainty among prospective teachers, which in turn increases their anxiety and worry. Therefore, it is difficult to say that prospective teachers have a positive attitude toward the AGS exam.

Preservice teachers were also asked what they expected the AGS exam to include. Some participants stated that they preferred the exam to be based on the courses they had studied at their faculty. Another group stated that an exam structure focused on the objectives of the curriculum in the schools where they would teach would be more appropriate. Some prospective teachers argued that an exam combining these two approaches would be more effective.

On the other hand, some prospective teachers stated that administering a uniform exam across all branches is inappropriate and that separate exams should be administered for each branch. For example, they believe it would be unfair to subject a graduate of art education and a prospective science teacher to the same exam, and they believe that specialized exam structures will provide a more robust evaluation environment.

Recommendations

Providing sufficient information to prospective science teachers about the AGS (Candidate Development Exam), which will be administered for the first time this year, is crucial both to ensure accurate results in line with the exam's objectives and to alleviate candidate anxiety.

It is recommended that the content of the upcoming AGS exam be structured to encompass the courses prospective teachers take in education faculties. Furthermore, linking the exam content to the courses taught in the schools where teachers will work could allow candidates to more effectively demonstrate their professional competencies. Differentiating the exam based on prospective teachers' fields of study and preparing separate exams for each field could ensure more equitable and relevant assessment and evaluation processes.

This study is based solely on the opinions of science teacher candidates. Therefore, comparing the findings of similar studies with teacher candidates from different fields will contribute to a more comprehensive understanding of the impact of the new examination system on teacher candidates.

References

Akcanca, N. (2020). Teacher Candidates' Perspectives about Applied 'Basic Science in Primary Education' Course, *Educational Policy Analysis and Strategic Research 2020*, Vol. 15(2) 7-24.

Gotwals, A., W., & Birmingham, D. (2015). Eliciting, Identifying, Interpreting, and Responding to Students' Ideas: Teacher Candidates' Growth in Formative Assessment Practices. *Res Sci Educ* (2016) 46:365–388.

Keçeci, G., Zengin, F. K. (2017). Observing the technological pedagogical and content knowledge levels of science teacher candidates. *Educational Research and Reviews*. Vol. 12(24), pp. 1178-1187.

Küçükaydın, M. A., and Gökbulut, Y. (2020). Beliefs of Teacher Candidates Toward Science Teaching. *Journal of Scıence Teacher Educatıon*, Vol. 31, No. 2, 134–150 https://doi.org/10.1080/1046560X.2019.1673603.

Johnson, J. H., & and Mawyer, K. N. (2019). Teacher Candidate Tool-Supported Video Analysis of Students'Science Thinking. *Journal of Scıence Teacher Educatıon*, Vol. 30, No. 5, 528–547 https://doi.org/10.1080/1046560X.2019.1588630.

Simon, J., Burstein, P. (1985). *Basic Research Methods in Social Sciences*, NewYork: Random Press.

Supeno, S., Prihandono, T., Mahardika, I. K., Sudarti, S., & Nuraini, L. (2022). Improving The Instructional Abilities of Science Teacher Candidates Through Lesson Study. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2778–2784. https://doi.org/10.29303/jppipa.v8i6.2595

URL 1. https://www.questionpro.com/blog/tr/arastirma-ve-yontemlerde-mulakat-turleri/#:~:text=M%C3%BClakat%2C%20genellikle%20kat%C4%B1l%C4%B1mc%C4%B1larla%20sohbet%20etmek,sorular%20ve%20cevaplar. Retrieved from the address on 14.04.2025.

SCIENCE TEACHER CANDIDATES' OPINIONS ABOUT THE COURSES THEY TOOK AT THE FACULTY

Gülen ÖNAL KARAKOYUN[1]

Abstract

This study aims to identify the strengths and weaknesses of the teacher training process by examining the general opinions of preservice science teachers regarding the courses they take at the faculty. The study, conducted using a qualitative research design, analyzed the individual assessments of 20 preservice teachers. Based on the data obtained, the majority of preservice teachers stated that the content of the subject matter courses was sufficient, emphasizing in particular the strong theoretical knowledge base. However, criticisms were also voiced regarding the limited number of practical training activities, inadequate laboratory facilities, and inadequate support for student participation in the teaching process. Candidates also expressed some shortcomings regarding the up-to-datedness of course content, the diversity of teaching methods, and the quality of academic advising services. In this context, it was concluded that courses such as teaching practice, material development, and instructional technologies should be conducted in a more functional and practice-based manner. The findings indicate that teacher preparation programs should not focus solely on the transfer of theoretical knowledge; they should also emphasize applied learning environments that support professional skills. Based on the research findings, recommendations were made to update program content, increase practice time, and adopt student-centered teaching approaches.

Keywords: Science, Prospective Teachers, Prospective Teachers' Opinions

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Introduction

Science teaching programs aim to equip pre-service teachers with both scientific content knowledge and effective teaching methods. These courses focus on developing students' scientific thinking, questioning, and argumentation skills. Additionally, course content often covers current educational approaches and active learning methods. Science teaching courses offer pedagogical content knowledge (PCK) on teaching core science areas such as biology, chemistry, physics, and earth sciences, as well as how to teach this knowledge. These courses enable pre-service teachers to both master the subject matter and develop student-centered teaching strategies (Sæleset, Friedrichsen, 2021; Conxita et al, 2020; Conxita et al, 2020). Programs often include practical courses alongside theoretical knowledge. Pre-service teachers gain experience in topics such as lesson planning, assessment, active learning techniques, and classroom practices (Ryan et al, 2019; Goodman, 2020; Kelly, 2014). Methods such as project-based learning, argumentation, discussion, and scientific process skills are prominent. These approaches enhance students' scientific thinking and problem-solving abilities (Kelly, 2014; Carla, 2009; Gunilla et al., 2022). Innovative methods such as the flipped classroom, active learning, and technology integration increase student engagement and motivation (Jin et al., 2022). Topics such as the nature of science, scientific methods, history of science, and philosophy of science are also included in science teaching courses. This enables pre-service teachers to understand how science works and the limits of scientific knowledge (Lindsay vdiğ, 2019; Sara et al, 2021; Till, 2014; Xiaoming, 2021; Ragnar, 2021; Fouad et al, 2000). The courses increase pre-service teachers' self-efficacy, scientific content knowledge, and pedagogical skills. In addition, the practice-oriented nature of the courses supports pre-service teachers in being more effective in classroom practices (Sæleset, Friedrichsen, 2021; Ryan et al, 2019; Ryan et al, 2024).

Prospective teachers' perceptions of the courses they take at their faculty reveal the strengths and weaknesses of the teaching process, enabling data-based evaluations for the development of curricula. In this context, the adequacy of theoretical course content, limited practice opportunities, teaching methods used in courses, and the quality of academic advising processes are among the primary factors directly impacting the professional development of prospective teachers. This study analyzes the general opinions of prospective science teachers regarding the courses they take at their faculty, aims to identify problems encountered in the teacher training process, and develop recommendations for improving this process. Prospective teachers' evaluations are considered an important source of data for reflecting current educational practices in the field and preparing them for the teaching profession.

Purpose of the Study

The purpose of this study was to examine the views of prospective science teachers on the courses they take at their respective faculties.

Study Method

This study employed the interview method. Interviews are a qualitative research technique that typically involves engaging in conversation with participants and asking open-ended questions to gather data on a topic. In most cases, the interviewer is a subject matter expert who aims to understand the participants' perspectives through a well-planned and implemented series of questions (URL 1).

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Study Sample

The sample for this study consisted of prospective science teachers studying at a university in eastern Turkey. The sample consisted of 20 students, 10 males and 10 females, who volunteered.

Data Collection Tools

A structured interview form, developed by the researcher, was used as the data collection tool in this study. After the interview form was prepared by the researcher, it was presented to three academics who are experts in the field. Following the feedback received, necessary corrections were made, and the form was finalized.

Data Analysis

The study was analyzed using content analysis. Content analysis can be described as the process of quantifying and digitizing what people write and say. This method is based on categorizing what is written and said and investigating how frequently it is used (Simon, Burstein, 1985).

Findings

This study aimed to examine the opinions of prospective science teachers about the courses they take at their respective faculties. For this purpose, prospective science teachers studying at a university in eastern Turkey were selected as a sample. An interview form developed by the researcher was administered to these prospective teachers. The questions asked and the responses received during the interviews are presented below.

Q1. What are your positive opinions about the courses you took while studying at the faculty?

The answers to Question 1 are provided below.

S1. Thanks to the science laboratory practices, my experimentation skills improved, and I feel more prepared for teaching.

S2. Field knowledge courses helped me learn the subjects in depth. I didn't feel any shortcomings after graduation.

S3. I learned about active learning models in the teaching methods and techniques course, and I found them very useful when applying them in the classroom.

S4. The educational psychology courses were very useful in getting to know and understand students.

S5. I learned how to design experiments in the science process skills course. I can apply this skill in the field.

S6. The faculty members were very attentive and taught physics topics in a very understandable way.

S7. I learned to use digital tools in technology-supported instruction, making me a modern teacher.

S8. During my internship, I delivered successful lectures using the methods I learned at the faculty.

S9. The lessons in science education, which included drama, creative activities, and group work, made learning very enjoyable.

S10. The measurement and evaluation courses helped me analyze student achievement objectively.

S11. The exercises in the biology laboratory gave me confidence in using a microscope.

S12. The teaching practice course helped me put theoretical knowledge into practice; it was invaluable.

S13. The science education course showed me how effective student-centered teaching is.

S14. Our academic advisors provided excellent guidance on course selection and professional development.

S15. When chemistry courses were taught with laboratory support, the topics became much more understandable, and lasting learning was achieved.

S16. The sociology of education course developed my understanding of how to approach different student profiles.

S17. Preparing and presenting experiments in the science activities planning course greatly benefited me.

S18. The pedagogical formation courses significantly contributed to the development of my teacher identity.

S19. I learned to think from multiple perspectives thanks to the interdisciplinary teaching methods I learned at the faculty.

S20. The material development courses were especially useful; I can easily prepare my own materials in class.

Q2. What are your negative opinions about the courses you took at the faculty?

The answers to question 2 are provided below.

S1. The courses at the faculty were very theoretical, with insufficient emphasis on practical applications.

S2. Laboratory courses were mostly lectures, and we had very few opportunities to experiment.

S3. Current teaching models were not sufficiently addressed in the teaching methods and techniques course.

S4. Physics courses were taught very superficially, and I especially struggled with abstract topics.

S5. The chemistry lab lacked the necessary equipment, and practical applications were often not possible.

S6. The measurement and evaluation course was very theoretical and not supported by real-world classroom practice.

S7. The material development course consisted solely of lectures without demonstrations of sample materials, which was ineffective.

S8. I did not learn enough to analyze student behavior in the educational psychology course.

S9. The internship period was too short, and we were not given enough time to apply what we learned.

S10. Student participation in classes was almost never encouraged; it was always instructor-focused.

S11. Course content was outdated, and students were still following the old curriculum.

S12. Courses like history and philosophy of science were not given sufficient attention; they weren't even offered as electives.

S13. Most courses were exam-focused, and we were encouraged to memorize rather than learn.

S14. Pedagogical formation courses were superficial, and important topics like classroom management weren't supported by practical experience.

S15. Because biology topics weren't covered in detail, I learned some basic information incompletely.

S16. Courses were taught in a disjointed manner, without establishing interdisciplinary connections.

S17. New tools weren't introduced in the technology-supported learning course; presentations were limited to PowerPoint.

S18. I was bored by the fact that lectures were limited to slides without practical application.

S19. Academic advising support was inadequate, and we were often left alone in choosing courses.

S20. The science education course was inadequate for field preparation; sample plans were very few.

Q3. What are your general opinions about the courses you took while studying at the faculty?

The answers to Question 3 are provided below.

S1. The faculty courses were sufficient in theory, but more emphasis should have been placed on practical applications.

S2. Field courses were strong; I learned a lot, especially from biology and chemistry, but the pedagogical courses were inadequate.

S3. Experimental studies were lacking, but the strategies I learned in the teaching methods course were very helpful.

S4. The course content was generally satisfactory, but it didn't fully integrate because it wasn't supported by classroom practice.

S5. I gained fundamental knowledge and perspectives about the teaching profession, but there were few concrete applications I could apply in the field.

S6. I didn't have many opportunities to apply what I learned outside of my internship, but my theoretical background is still strong.

S7. Some courses focused solely on exam-oriented explanations, which hindered sustained learning.

S8. Science education courses were invaluable, but a lack of laboratory equipment made learning difficult.

S9. The quality of the faculty education, combined with my personal effort, was sufficient, but this may not be true for everyone.

S10. Aside from the teaching practice course, it was difficult to find opportunities to apply the knowledge we learned in a classroom setting.

S11. Educational science courses were generally beneficial, but field courses were more based on memorization.

S12. Science course content was sometimes challenging, but faculty members were supportive.

S13. Courses were generally traditional, with limited active participation.

S14. Material development and instructional technologies courses improved my teaching skills.

S15. Courses such as measurement and evaluation were inadequate in teaching me how to conduct assessments in the classroom.

S16. We received a strong foundation in theoretical courses, but more internships were necessary for professional experience.

S17. If the science education course had been integrated with classroom management, it would have been a more holistic education.

S18. I had difficulty making connections between disciplines because the courses were separate and disjointed.

S19. Most of the courses were useful, but the content should be revised according to more current scientific developments.

S20. Overall, I received a good education, but the lack of practice did not fully develop my professional confidence.

Conclusion

This study examined the general evaluations of science teacher candidates regarding the courses they take at their faculty. Based on the candidates' opinions, it appears that the transfer of theoretical knowledge in university education is largely sufficient; subject-matter courses, in particular, provide a strong foundation in terms of content. However, it was stated that this theoretical knowledge is not adequately supported by practical application. The candidates highlighted various structural shortcomings, such as limited laboratory practice, teaching methods that are primarily lecture-based, and low student participation.

While some participants viewed the guidance role of faculty members positively, there were also criticisms that academic advising services and individual guidance were inadequate. Furthermore, dissatisfaction with the up-to-date nature of course content suggests that contemporary teaching approaches have not been adequately integrated into the educational process. These findings suggest that teacher preparation programs should focus not only on knowledge transfer but also on the development of practical skills. In applied fields such as science education, integrating theory and practice with a holistic approach will enhance the professional competencies of prospective teachers. Restructuring educational programs, integrating current educational technologies, and improving the quality of internships will significantly contribute to the professional development of prospective teachers.

Recommendations

-Courses that include hands-on training (laboratory, microteaching, internships) can be increased.

-Course content can be updated to align with contemporary science teaching approaches.

-Student-centered teaching strategies can be further encouraged.

-Advisory systems and individual academic support mechanisms can be strengthened.

References

Carla Zembal-Saul. (2009). Learning to Teach ElementarySchool Science as Argument. Published online 27 April 2009 in *Wiley InterScience* (www.interscience.wiley.com).

Conxita Márquez Bargalló, J. D. Casal, Begoña Oliveras Prat, Víctor López Simó. (2020). Teaching Physics and Chemistry. https://consensus.app/papers/teaching-physics-and-chemistry-casal-prat/30665a1f619d55f7ba255d43fad2ba32/ Available at: 15.07.2025

Conxita Márquez Bargalló, J. R. Muñoz, J. D. Casal, A. Tallada, Víctor López Simó. (2020). Teaching Biology and Geology. https://consensus.app/papers/teaching-biology-and-geology-casal-bargall%C3%B3/d7ddb1f26d285292b7bbeffc2816ad10/ Available at: 15.07.2025.

Fouad Abd-El-Khalick, and Norman G. Lederman. (2000). The InØuence of History of Science Courses on Students' Views of Nature of Science. *Journal of Research In Scıence Teachıng* Vol. 37, No. 10, Pp. 1057-1095.

Goodman, B. (2020). Fundamentals of Teaching in the Basic Sciences. *The FASEB Journal.* https://doi.org/10.1096/fasebj.2020.34.s1.02066

Gunilla Öberg, Alice Campbell, Joanne Fox, Marcia Graves, Tara Ivanochko, Linda Matsuchi, Isobel Mouat, Ashley Welsh. (2022). Teaching Science as a Process, Not a Set of Facts. *Science & Education* (2022) 31:787–817.

Jin Su Jeong, David González-Gómez, and Florentina Cañada-Cañada. (2021). How does a flipped classroom course affect the affective domaintoward science course? *Interactıve Learnıng Envıronments* 2021, Vol. 29, No. 5, 707–719https://doi.org/10.1080/10494820.2019.1636079.

Kelly, N. (2014). Teaching Science in Elementary and Middle School: A Project-Based Approach. *Interdisciplinary Journal of Problem- Based Learning*, 8(1). Available at: htp://dx.doi.org/10.7771/1541-5015.1489

Lindsay B. Wheeler, Bridget K. Mulvey, Jennifer L. Maeng,Mila Rosa Librea-Carden, and Randy L. Bell. (2019). Teaching the teacher: exploring STEM graduate students'nature of science conceptions in a teaching methods course. Internatıonal *Journal of Scıence Educatıon* 2019, Vol. 41, No. 14, 1905–1925https://doi.org/10.1080/09500693.2019.1647473.

Ragnar Fjelland. (2021). Teaching Philosophy of Science to Science Students: An Alternative Approach. *Studies in Philosophy and Education* (2022) 41:243–258.

Ryan Downey, S. Mulroney, A. Myer (2019). Creating a Course in Science Teaching to Address the Needs of Graduate Trainees. *The FASEB Journal*. https://doi.org/10.1096/fasebj.2019.33.1

Ryan S. Nixon, Alexandra Dorine Swain. (2024). Do College Science Courses Help Preservice Elementary Teachers Learn the Science They Need to Teach? *Journal of Science Teacher Education*. P 661-675, https://doi.org/10.1080/1046560X.2024.2323784

Sæleset J, Friedrichsen P. (2021). A case study of specialized science courses in teacher education and their impact on classroom teaching. *Journal of Science Teacher Education*. 2021

Sara Green, Hanne Andersen, Kristian Danielsen, Claus Emmeche, Christian Joas, Mikkel Willum Johansen, Caio Nagayoshi, Joeri Witteveen, Henrik Kragh Sørensen. (2021). Adapting practice-based philosophy of science to teachingof science students. *European Journal for Philosophy of Science* (2021) 11: 75.

Simon, J., Burstein, P. (1985). *Basic Research Methods in Social Sciences*, NewYork: Random Press.

Till Grüne-Yanoff. (2014). Teaching philosophy of science to scientists: why, what and how. *Euro Jnl Phil Sci* (2014) 4:115–134.

URL 1. https://www.questionpro.com/blog/tr/arastirma-ve-yontemlerde-mulakat-turleri/#:~:text=M%C3%BClakat%2C%20genellikle%20kat%C4%B1l%C4%B1mc%C4%B1larla%20sohbet%20etmek,sorular%20ve%20cevaplar. Available at: 14.04.2025.

Xiaoming Shi. (2021). Using Explicit Teaching of Philosophy to Promote Understanding of the Nature of Science. *Science & Education* (2021) 30:409–440.

SCIENCE TEACHERS' OPINIONS ABOUT THE MODERN CENTURY EDUCATION MODEL

Gülen ÖNAL KARAKOYUN[1]

Abstract

The purpose of this study is to examine science teachers' views on the Muaarif Century Education Model and to provide a comprehensive assessment of the model's applicability, strengths, and weaknesses. This study, conducted using a qualitative research design, collected data from 20 science teachers through semi-structured interviews. The data were systematically analyzed using content analysis. The research findings reveal that science teachers positively evaluated the model's student-centered teaching approach, its emphasis on scientific process skills, its integration of technology, and its support for interdisciplinary learning from a pedagogical perspective. However, structural and contextual problems encountered during the implementation process are also noteworthy. Participants noted that implementing the model without adequate in-service training support, coupled with factors such as class sizes, inadequate infrastructure, and content density, created various challenges in implementation. In conclusion, science teachers view the Muaarif Century Education Model as a visionary reform initiative; however, they emphasize that for the model to be successful, it requires ensuring effective teacher participation in the process, adapting implementations to local conditions, and systematic monitoring and evaluation processes. In this context, the findings contribute to the development of recommendations to increase the model's applicability in the field.

Keywords: Science, Muaarif Century Education Model, Teachers' Views

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Introduction

In today's world, the rapid increase in access to information, the penetration of technology into every aspect of social life, and the increasing complexity of the problems faced by individuals have led to radical transformations in education systems. The Muaarif Century Education Model, which emerged as a reflection of this transformation, represents an innovative paradigm shift in Turkey's education policies. The model aims to develop individuals who can adapt to the multifaceted needs of the 21st century, think critically, are open to collaboration, and possess advanced technological literacy (Sumera et al., 2023; Afandi et al., 2019). In this context, the professional competencies required of science teachers are being redefined and expanded. The literature emphasizes that science teachers should be equipped not only with content knowledge but also with essential 21st-century skills (4Cs) such as communication, collaboration, critical thinking, and creativity. Furthermore, it is stated that information and communication technologies (ICT), media literacy, character education, and values education should also be included among teacher competencies. These multifaceted skills require teachers to be guides who not only convey knowledge but also direct learning and place the student at the center (Sumera et al., 2023; Afandi et al., 2019).

The social constructivist approach, one of the innovative pedagogical approaches in science education, envisions teachers assuming a role that supports decentralized learning environments that are open to change and paves the way for active student participation. In this context, the creation of an interactive and collaborative learning environment is encouraged by integrating Web 2.0 tools, cloud-based applications, and digital content into the teaching process. However, research reveals that teacher educators do not adequately model these technologies in classroom practices and that teachers have difficulties using these tools effectively (Barak, 2017; Sumera et al., 2023). On the other hand, the quality of pre-service and in-service training processes stands out as a decisive factor in teachers' acquisition of 21st-century skills and their integration into teaching processes. Incorporating STEM education and real-world problems into course content in these processes creates an increasing effect on students' scientific awareness and career interests (Almazroa, Alotaibi, 2023; Dare et al., 2021).

Accordingly, examining science teachers' views on the Maarif Century Education Model will contribute to identifying the model's strengths and areas requiring improvement. Teachers' perceptions of the model help understand the opportunities and limitations encountered during implementation and also provide important clues regarding the adaptability of policies to the field. The purpose of this study is to reveal science teachers' general opinions on the Maarif Century Education Model, to evaluate their positive and critical perspectives from an academic perspective, and to develop recommendations for more effective implementation of the model.

Purpose of the Study

The primary objective of this study is to examine science teachers' views on the Maarif Century Education Model to reveal their perceptions of the model in the field and their evaluations of its implementation. In this context, teachers' perspectives on both the model's strengths and the challenges they encountered during its implementation were analyzed in depth.

Research Method

This study was structured based on a qualitative research design. Semi-structured interviews were used as the data collection method. Interviews were chosen as an effective method for obtaining in-depth data because they allowed participants to express their experiences and thoughts in their own words. During this process, which used open-ended questions, the researcher aimed to collect data using a holistic approach by directly interacting with the participants (URL 1).

Study Group (Sample)

The study group consisted of 20 science teachers working in a province in eastern Turkey. The sample was selected for maximum diversity and volunteerism. The demographic distribution of the participants consisted of 10 female and 10 male teachers, allowing for a balanced reflection of diverse perspectives.

Data Collection Tool

Data were collected through a semi-structured interview form developed by the researcher. To ensure the validity of the interview form, the prepared questionnaire was presented to three academics specialized in the field, and the form was finalized after necessary adjustments were made based on the feedback received from these experts. The questions covered teachers' general assessments of the Muaarif Century Education Model, their observations regarding its implementation, and their thoughts on the model's impact.

Data Analysis

The qualitative data obtained were analyzed using content analysis. Content analysis is an analytical process that involves systematically coding data obtained from participants' statements, classifying them into themes, and aggregating them under specific categories (Simon & Burstein, 1985). Using this method, teachers' opinions were grouped under specific themes, and exemplary quotes and interpretations were included under each theme.

Findings

This study aimed to examine science teachers' opinions about the Muaarif Century Education Model. For this purpose, a sample of science teachers teaching in a province in eastern Turkey was selected. An interview form developed by the researcher was administered to these teachers. The questions asked and the responses received during the interviews are presented below.

Q1. What are your positive opinions about the Muaarif Century education model?

Responses to Question 1 are provided below.

T1. Teachers believe that the Muaarif Century Education Model's encouragement of interdisciplinary approaches is important for developing students' scientific thinking and problem-solving skills.

T2. Science teachers consider the model's emphasis on student-centered teaching processes a development that will increase learning retention.

T3. Teachers find this model's adoption of a constructivist learning approach that supports critical and creative thinking skills pedagogically valuable.

T4. Participants believe that the skill-based outcomes included in the curriculum will increase students' scientific literacy levels.

T5. Science teachers consider the model's encouragement of effective use of technological tools as a step in line with the needs of the age.

T6. The Muaarif Century Education Model's prioritization of inquiry-based learning is viewed by teachers as a supportive element of the scientific process.

T7. Teachers find this model's ability to connect students to daily life and science positive because it makes learning meaningful.

T8. The majority of participants stated that the model's provision of professional development opportunities for teachers would be effective in enhancing professional competencies.

T9. Science teachers find the model's emphasis on environmental and sustainability themes beneficial in raising environmental awareness.

T10. Teachers have a positive attitude toward the model's flexible applications that consider diverse learner needs and state that it offers an inclusive educational approach.

T11. Teachers consider the Muaarif Century Education Model's innovative approach to assessment and evaluation processes to be an opportunity for more accurate assessment of student achievement.

T12. Teachers view the model's goals of strengthening science laboratory practices as an opportunity to support students' learning through experience.

T13. Participants considered the model's focus on the development of scientific process skills a strategic move in science education.

T14. Science teachers find the model's focus on developing digital literacy skills highly appropriate for technology-supported instruction.

T15. Teachers consider the model's emphasis on social and emotional development, as well as academic achievement, a positive aspect for students' holistic development.

T16. Participants view the model's integration of local and universal values in curricula as an element that enhances the effectiveness of values education.

T17. Science teachers argue that the model's encouragement of active learning methods will increase student engagement and motivation in class.

T18. Teachers believe that the model's aspects that strengthen collaboration among colleagues will directly contribute to the quality of teaching.

T19. Participants believe that the model's inclusion of teaching strategies that support scientific curiosity and a desire for discovery increases students' interest in science classes.

T20. Teachers viewed the Muaarif Century Education Model's aim for a holistic transformation in education as a promising step for the development of the national education system.

Q2. What are your negative opinions about the Muaarif Century education model?

The responses to Question 2 are provided below.

T1. Science teachers stated that sufficient in-service training was not provided regarding the implementation of the model, and that this could lead to problems in implementation.

T2. Participants stated that some concepts included in the model remained theoretical and did not fully align with classroom realities.

T3. Teachers stated that the multidimensional structure of the model complicated curriculum and caused teachers difficulties in implementation.

T4. Some teachers argued that the model ignored class sizes and equipment shortages, making equitable and effective implementation impossible.

T5. Participants noted that infrastructure problems experienced in accessing the digital tools and platforms included in the model could negatively impact learning processes.

T6. Teachers stated that the multifaceted roles assigned to teachers by the model increased their workload and fostered feelings of burnout.

T7. Science teachers stated that some aspects of the model were implemented quickly and without sufficient piloting, making sustainability difficult.

T8. Participants emphasized that the lack of a clear framework for the model's assessment and evaluation processes led to differences in implementation among teachers.

T9. Teachers stated that the model offers superficial updates to science teaching content and is insufficient to support in-depth understanding.

T10. Science teachers stated that the model does not fully reflect the local context and has low applicability, especially in rural areas.

T11. Participants argue that the model does not offer sufficient flexibility to accommodate students' individual differences, creating a disadvantage in the learning process.

T12. Teachers stated that although the model encourages interdisciplinary practices, collaboration between teachers is inadequate and unsupported in the current system.

T13. Science teachers pointed out that although the model prioritizes technology integration, it can be challenging for teachers with low technological proficiency levels.

T14. Participants stated that the transformation targeted by the model is not sufficiently embraced by school administrations, leading to a loss of motivation in implementation.

T15. Teachers stated that although the model emphasizes science laboratory practices, the lack of laboratory facilities in schools renders this goal meaningless.

T16. Science teachers stated that time constraints were experienced during the integration of the updated objectives in the model into the curriculum.

T17. Participants emphasize that the innovative methods envisioned in the Maarif Century Model conflict with traditional exam systems, creating a disconnect in practice.

T18. While teachers viewed the model's goal of supporting scientific process skills positively, they noted that insufficient time was allocated to this goal in the classroom.

T19. Science teachers stated that the model was not effective enough in increasing students' interest in science courses and that it did not directly impact student motivation.

T20. Participants believed that the Muaarif Century Education Model was not developed based on teachers' opinions and experiences, and therefore lacked a practical understanding.

Q3. What are your general opinions about the Muaarif Century education model?

The responses to Question 3 are provided below.

T1. While science teachers welcome the Muaarif Century Education Model's reliance on contemporary educational approaches, they express that preparations for implementation are inadequate.

T2. While participants find the model's encouragement of student-centered teaching processes pedagogically valuable, they also stated that current class hours are insufficient to support this structure.

T3. Teachers consider the model's interdisciplinary approach to science teaching a development that enhances scientific integrity.

T4. Some teachers emphasized that the model's emphasis on technology use is important for acquiring 21st-century skills, but that technological infrastructure varies from school to school.

T5. Participants support the model's approach prioritizing equal opportunities in education, but they note that socioeconomic disparities hinder this equality in practice.

T6. Science teachers viewed the model's structure, which encourages scientific process skills and inquiry-based learning, as a positive step for science education.

T7. However, some teachers stated that the model's conceptual framework was not sufficiently clear, creating ambiguities in implementation.

T8. Teachers emphasized the importance of restructuring assessment and evaluation approaches, but stated that this process was not adequately introduced to teachers and that support was limited.

T9. Participants support the model's goal of providing students with meaningful learning experiences relevant to life, but they stated that the content density contradicts this goal.

T10. Science teachers find the model's emphasis on teacher professional development positive, but emphasize the need for more systematic and sustainable support mechanisms.

T11. While teachers appreciate the model's emphasis on laboratory-based learning, they noted that the materials and time required to implement these practices in schools are insufficient.

T12. Participants believe the model can increase students' interest in science classes, but they emphasize that active teacher participation is essential for the implementation to be successful.

T13. Some teachers find the model's aim for a holistic transformation in education promising; however, they state that systemic changes create uncertainty and anxiety among teachers.

T14. Science teachers consider the model's inclusion of social-emotional learning important for students' holistic development, but they state that it is unclear how this aspect will be integrated into the curriculum.

T15. Participants stated that the model supports structures that are sensitive to student differences, but concrete strategies for addressing these differences in classroom practice have not yet been sufficiently developed.

T16. Teachers emphasize that the transformation targeted by the model encompasses a long-term process and therefore requires patient, planned, and gradual implementation.

T17. Some teachers state that the model is theoretically sound, but it does not sufficiently consider teachers' experiences, needs, and feedback from the field.

T18. Participants find the educational model's effort to integrate values education and scientific education meaningful, but they note that achieving this balance can be challenging during implementation.

T19. Science teachers expressed concern that some centralized aspects of the model could limit teacher initiative.

T20. Teachers generally emphasize that the Muaarif Century Education Model offers a visionary approach, but that greater teacher involvement is necessary for this vision to be realized in the field.

Conclusion

This study aimed to reveal science teachers' perceptions and evaluations of the Maarif Century Education Model. The findings, based on qualitative data, indicate that teachers balanced both positive and critical aspects of the model. Science teachers consider the model's reliance on contemporary educational approaches, its support for student-centered teaching, and its emphasis on scientific process skills to be a positive pedagogical development. Furthermore, the model's encouragement of interdisciplinary learning, emphasis on technology integration, and efforts to strengthen science laboratory practices are seen as having the potential to enhance the quality of science education. This structure, which aims to provide students with meaningful and lasting learning experiences that connect to daily life, is generally considered a visionary transformation by teachers.

However, teachers also highlighted several challenges regarding the model's applicability. They noted that factors such as inadequate in-service training for teachers, a lack of technological infrastructure, overcrowded classrooms, and content density make effective implementation of the model challenging. They also emphasized that the model's conceptual framework remains unclear in the field, that teachers are insufficiently informed about this new structure, and that support mechanisms remain limited during the implementation process. Teachers emphasized that for the transformation targeted by the Muaarif Century Education Model to be successful, local conditions must be considered, active teacher participation in the process must be ensured, pilot projects must be increased, professional development opportunities expanded, and implementation processes must be planned in stages.

As a result, science teachers view the Muaarif Century Education Model as a reform initiative with potential, but one that may face various structural, pedagogical, and infrastructural challenges in implementation. In this context, the model's success depends on adopting a participatory, flexible, and context-sensitive approach that takes teachers' views into account. It is once again crucial that teachers be viewed not only as implementers but also as stakeholders and guides in the implementation of education policies.

Recommendations

1. For teachers to effectively implement the Muaarif Century Education model, comprehensive and ongoing in-service training programs are necessary. These programs can be structured to cover both the theoretical foundation of the model and its classroom applications.

2. Given the model's prioritization of technology integration and laboratory-based practices, it is crucial to create equally equipped learning environments across all schools. Science laboratories, in particular, may need to be equipped to meet standards.

3. The model's transition to the field should be gradual, taking into account teachers' preparedness levels and local conditions. It is recommended to gain experience through pilot implementations and update the implementation process based on data, rather than sudden and large-scale transitions.

4. Given the model's emphasis on learning-based assessment, it is important to develop alternative and holistic assessment tools instead of traditional exams. Increasing teachers' assessment literacy should also be supported during this process.

References

Afandi, Sajidan, M. Akhyar, N. Suryani. (2019). Development Frameworks of The Indonesıan Partnershıp 21st-Century Skılls Standards for Prospectıve Scıence Teachers: A Delphı Study. *JPII* 8 (1) (2019) 89-100.

Almazroa, H.; Alotaibi, W. (2023). Teaching 21st Century Skills: Understanding the Depth and Width of the Challenges to Shape Proactive Teacher Education Programmes. *Sustainability* 2023, 15, 7365. https://doi.org/10.3390/su15097365

Barak, M. (2017). Science Teacher Education in the Twenty-First Century: a Pedagogical Framework for Technology-Integrated Social Constructivism. *Res Sci Educ* (2017) 47:283–303. DOI 10.1007/s11165-015-9501-y

Dare, E. A., Keratithamkul, K., Hiwatig, B.M., Li, F. (2021). Beyond Content: The Role of STEM Disciplines, Real-World Problems, 21st Century Skills, and STEM Careers within Science Teachers' Conceptions of Integrated STEM Education. *Educ. Sci*. 2021, 11, 737. https://doi.org/10.3390/educsci11110737.

Simon, J., Burstein, P. (1985). *Basic Research Methods in Social Sciences*, NewYork: Random Press.

Sumera Imran, Shabeena Shaheen, Hina Waseem, Arshad Ali. (2023). Transformation of 21st Century Science Skills: Perceptions of Secondary School Teachers. *Journal of Social Sciences and Humanities*, Vol. 4 No. 3

URL 1. https://www.questionpro.com/blog/tr/arastirma-ve-yontemlerde-mulakat-turleri/#:~:text=M%C3%BClakat%2C%20genellikle%20kat%C4%B1l%C4%B1mc%C4%B1larla%20sohbet%20etmek,sorular%20ve%20cevaplar. Avilable at: 14.04.2025.