JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

This is an open access article under the Creative Commons Attribution 4.0 International License

EFFECTIVE USE OF ARTIFICIAL INTELLIGENCE TOOLS IN STEM EDUCATION: PERSPECTIVES OF STEM EDUCATORS

Ahmet Uyar

Abstract. *This study investigates the perspectives of STEM (Science, Technology, Engineering, and Mathematics) educators in Türkiye regarding the integration of Artificial Intelligence Tools (AITs) into STEM education (STEM-e). The research was conducted to address the lack of comprehensive studies exploring educators' experiences, challenges, and the perceived impact of AITs on student outcomes. Adopting a phenomenological research design, data were collected through semi-structured interviews with 15 STEM educators who actively use AITs in their teaching practices. Purposive sampling was used to select STEM educators who actively and consistently integrate AITs into their instructional practices, ensuring firsthand experience with AI-based tools in the classroom. The findings revealed that educators perceive AITs as beneficial for saving time, personalizing instructional content, and enhancing student motivation. However, challenges such as limited pedagogical alignment, accessibility issues, inaccurate feedback, and technical infrastructure deficiencies were also reported. Furthermore, while the mindful use of AITs was found to support students' cognitive and emotional development, excessive or uncritical use may hinder their problem-solving and critical thinking skills. The results underscore the need for educational policymakers and institutions to strengthen technological infrastructure, provide support and training for educators, and implement pilot programs. Additionally, policymakers are encouraged to prioritize user-friendly design and data security to increase the accessibility and effectiveness of AITs in education.*

Keywords: *STEM education, Artificial Intelligence Tools, STEM educators.*

Ahmet Uyar
Hatay Mustafa Kemal University, Türkiye

Introduction

In an era increasingly shaped by technological advancements, the integration of artificial intelligence (AI) into educational environments has emerged as a transformative force. In this context, the role of AI in education is considered not just as a technological innovation but as a catalyst that fundamentally reshapes learning processes. Specifically, the opportunities AI offers in education have the potential to make teaching and learning practices more personalized, effective, and accessible. Artificial intelligence in education is a dynamic and interdisciplinary domain that integrates AI technologies to enhance teaching strategies, enrich learning experiences, and refine assessment methods (Chen et al., 2020; Hwang et al., 2020).

Within this domain, AI applications in STEM-e represent a specialized area dedicated to designing and utilizing AI-driven tools to enhance and support STEM-e (Xu & Quyang, 2022). Recent studies have also shown that AI-based tools such as ChatGPT can support personalized learning, provide real-time feedback, and improve students' engagement and outcomes in STEM subjects (Javaid et al., 2023; Bahrami et al., 2023; Wu et al., 2023). These tools can also support teachers by helping them plan lessons, assess students' work, and suggest appropriate learning resources (Karaman & Goksu, 2024; Van Den Berg & du Plessis, 2023). As such, AI technologies are increasingly viewed as essential components in the design of responsive and inclusive STEM learning environments.

As AI becomes more embedded in education systems, it has also received growing attention in both international and national STEM-e policies. For instance, the U.S. STEM-e Policy (2013–2018) emphasized early childhood to post-secondary STEM learning, equitable access, teacher training, and inter-agency collaboration to sustain leadership in science and innovation. Similarly, the United Kingdom and Ireland have positioned STEM-e —and particularly the integration of AI—as central to economic development, skill-building, and educational equity. Ireland's 2017–2026 policy strategy includes early childhood engagement, inclusive participation, collaboration with industry, and long-term planning for AI-supported learning (Ay & Seferoğlu, 2021).

In Türkiye, research on the use of AI in STEM-e has also gained momentum. For example, Uğraş et al. (2024) investigated the application of ChatGPT in early childhood STEM-e, while Bayram and Çelik (2023) examined how AI-based tools affect students' skill development. However, these studies often

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

focus on early education or a single tool and do not reflect the broader use of various AI technologies in integrated STEM settings. This highlights a significant gap in the literature, particularly regarding how educators who deliver STEM-e in a multidisciplinary and integrated manner experience AI technologies in their instructional practices.

Building on this global and local context, it is essential to recognize that STEM-e functions as a dynamic system composed of interrelated components, including content, instructional media, learning environments, and key participants such as educators and learners (Gökçe-Tekin et al., 2023; Smith-Mutegi et al., 2025). It emphasizes the integration of science, technology, engineering, and mathematics to promote critical thinking, problem-solving, and interdisciplinary understanding (Kennedy & Odell, 2014). The incorporation of AI as a fundamental technological component necessitates a thoughtful approach to these interrelated aspects to ensure the effective implementation of STEM-e. STEM-e encompasses multiple interconnected elements, including key participants (such as students and educators), knowledge areas (covering both disciplinary and interdisciplinary content), technological resources (such as digital tools used in schools), and learning contexts (including classrooms, policies, and educational culture). Providing effective STEM-e requires a holistic approach that considers social, pedagogical, and environmental factors (Kim et al., 2022; Xu & Ouyang, 2022). Therefore, gaining a deep understanding of AI integration in STEM-e is essential to optimize its advantages for both students and educators, while improving teaching and learning experiences (Smith-Mutegi et al., 2025).

Despite the potential benefits, educators still face notable challenges in incorporating AI into STEM-e. These include designing engaging and relevant STEM tasks, monitoring student progress, and assessing learning outcomes effectively. AI technologies can help address these challenges by enabling more adaptive and data-informed learning environments, automating task generation, and supporting personalized assessment processes (Kim, 2023). However, research also warns of issues such as AI bias, ethical risks, data privacy, and over-dependence on AI tools (Tatineni, 2019; Vincent-Lancrin & Van der Vlies, 2020), underlining the need for a balanced and critically reflective approach.

In light of these developments, this study aims to explore STEM educators' experiences with incorporating AITs into STEM-e, examining how AI technologies shape teaching methods, the challenges faced by educators, their effects on student learning, and concerns regarding AI use in STEM-e. By providing insights into the thoughtful and effective application of AITs, this research aims to expand practical knowledge on AI integration in STEM-e. Additionally, the findings are valuable in terms of shaping educational policies and educational strategies by addressing both the potential benefits and challenges of implementing AI in STEM learning environments.

The Problem and Significance of the Research

The swift progress of AI technologies is bringing notable transformations to education, especially in STEM fields. The incorporation of AITs into STEM-e offers opportunities to enrich student learning experiences and reshape teaching methods. These tools support problem-solving, innovation, and optimization, enabling students to develop solutions to real-world challenges. Moreover, AI-powered technologies offer educators valuable insights by facilitating data-driven analysis of student performance, supporting pedagogical research, and informing evidence-based teaching strategies. Maximizing the potential of AI in STEM-e requires further investigation into how educators integrate these technologies and their effects on both teaching methods and student learning outcomes. However, there is still a lack of extensive research focusing on educators' experiences, the challenges they face, and the overall impact of AI integration on student outcomes.

Existing literature includes studies exploring science teachers' perspectives on integrating AI technologies into science education (Alshorman, 2024; Yılmaz, 2024) and comprehensive reviews on the role of AI in STEM-e (Chng et al., 2023; Hashim et al., 2021; Holmes et al., 2019; Joseph & Uzondu, 2024; Xu & Ouyang, 2022). Additionally, research has examined parental views on AI-based chatbots like ChatGPT in STEM-e (Feser, 2024), compared teachers' attitudes toward AI in STEM versus non-STEM disciplines (Parviz, 2024), analyzed the integration of ChatGPT into early childhood STEM-e (Uğraş et al., 2024), and assessed the impact of AITs on student skill development (Bayram & Çelik, 2023). However, apart from the study by Uğraş et al. (2024), research specifically addressing the use of AITs in STEM-e remains scarce. Moreover, that study is limited to early childhood STEM-e and focuses solely on ChatGPT. Given this gap, the present study, which investigates the experiences of educators who actively use various AITs in STEM-e, offers a valuable contribution to understanding AI integration in STEM teaching and learning processes. Additionally, rather than focusing on STEM teachers in specific disciplines (such as mathematics or science), this research explores the perspectives of STEM educators who approach science, mathematics, engineering, and technology learning outcomes in an integrated manner. By specifically examining the experiences of educators

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

who deliver integrated STEM-e and actively utilize multiple AITs in their teaching processes, this study goes beyond the narrow focus of existing research, contributing originality to the literature.

The literature consistently highlights the need for research that facilitates the effective integration of AI technologies into STEM-e (Joseph & Uzondu, 2024). Zawacki-Richter et al. (2019) emphasized AI's potential to enhance peer interactions and facilitate collaborative problem-solving in STEM learning, highlighting the need for further investigation. Tatineni (2019) highlighted the need to address ethical issues like data privacy, algorithmic bias, and fairness in AI-based educational tools. Vincent-Lancrin and Van der Vlies (2020) emphasized the importance of ensuring equal access to AI technologies and creating tools that foster student engagement. Moreover, Hwang et al. (2020) emphasized the need for research on leveraging AI to strengthen teacher education programs, refine instructional methods, and assist educators in seamlessly incorporating AI into their teaching practices.

Specifically, there is a need for more comprehensive research on how STEM educators use AITs, the challenges they face in integrating these technologies into teaching, and the impact of AI-based teaching on student performance. This research seeks to provide insights into the more effective use of AI in STEM-e by focusing on educators' experiences with AI integration in STEM, exploring the benefits of these tools, the challenges of their implementation, their impact on students, and concerns related to ethics, security, and privacy. By addressing these factors, the study contributes to optimizing AI integration in STEM-e and serves as a useful resource for teachers, policymakers, curriculum developers, and technology designers.

Research Focus

This study examined STEM educators' experiences with AITs in STEM-e, focusing on both the advantages and challenges they encounter. It assessed the positive and negative impacts of these tools on students and addressed concerns related to ethics, security, and privacy. Furthermore, a central aspect of the research was to offer recommendations for teachers, policymakers, curriculum developers, and technology designers to improve the effective and informed integration of AITs in STEM-e.

Research Aim and Research Questions

This study aimed to explore STEM educators' views on the integration of AITs in STEM-e. In pursuit of this objective, the research focused on addressing the following key questions:

1. What are the experiences of STEM educators with AITs in STEM-e?
2. How do STEM educators perceive the role of AITs in supporting student learning and development?
3. What concerns do STEM educators have regarding the use of AITs in STEM-e?
4. What recommendations do STEM educators offer for improving the effectiveness of AITs in STEM-e?

Research Methodology

Design

This study employed a qualitative research design grounded in a phenomenological approach, aiming to explore the lived experiences of STEM educators who actively integrate AITs into their teaching practices. Phenomenology, as defined by Yıldırım and Şimşek (2018), focuses on understanding phenomena that individuals experience in their daily lives but may not fully comprehend. The research was conducted in Türkiye, specifically in the Mediterranean region, within the provinces of Hatay and Adana. Data were collected in October 2024 over a one-week period through semi-structured interviews. The sample consisted of 15 STEM educators teaching at the primary, middle, and high school levels. Participants were selected using purposive sampling based on the criterion that they actively used AITs in their instructional practices. The group included educators with varying years of teaching experience and from different gender backgrounds to ensure diversity in perspective. Ethical approval was obtained from the Hatay Mustafa Kemal University Scientific Research and Publication Ethics Committee for Social and Human Sciences on September 1, 2024.

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Participants

This study employed a purposive sampling method (Patton, 2002). Participants were selected from among STEM educators who actively use AITs in STEM-e. Accordingly, teachers working at two different STEM centers located in Hatay and Adana Provinces, located in Türkiye's Mediterranean region, were the participants of the study. The participant group consisted of nine males and six females. In terms of their educational background, four teachers held a master's degree, while eleven had a bachelor's degree. Regarding technological competence, twelve participants considered themselves highly competent, while ten had not undergone any AI-related education. Nonetheless, all participants stated that they actively follow technological advancements and utilize Web 2.0 tools. In terms of professional experience, three participants had 1–5 years of teaching experience, seven had 5–10 years, and five had 10–15 years of experience. All participants had been actively involved in STEM centers for the past seven years and had been using AI tools in educational practices for approximately three years.

Instrument and Procedures

The data for this study were gathered in October 2024. STEM educators from education centers in Hatay and Adana were contacted and invited to participate in the study. All the teachers who were contacted agreed to take part in the research. The interview dates were scheduled, and each of the 15 interviews was conducted via the Zoom platform. Each session lasted approximately 15–20 minutes and was recorded following the participants' verbal consent. The participants' responses were transcribed verbatim without any modifications, and pseudonyms were assigned for confidentiality. These pseudonyms ensured the participants' privacy during the presentation of the findings. A semi-structured interview guide with six questions was utilized for data collection. Table 1 displays a selection of questions from the semi-structured interview form, designed to investigate STEM educators' experiences with using AITs in STEM-e.

Table 1
Example Questions in the Interview Form

What advantages do AITs offer you in STEM-e? Could you describe a specific situation or event where these tools provided a benefit?
Can you describe your observations of the impact of AI-supported applications on students in STEM-e? Please share your experiences related to this.
What are your recommendations for more effective utilization of AITs in STEM-e?

Data Analysis

The recorded and transcribed interview data were imported into the QSR NVivo-11 software for qualitative analysis. Content analysis was utilized to analyze the data systematically by identifying themes, categories, and codes through keywords and expressions in the texts (Büyüköztürk et al., 2020). The primary objective of content analysis is to conceptualize the data obtained from the interviews, identify relationships between these concepts, and interpret them (Yıldırım & Şimşek, 2018). Additionally, this method allows for the identification of implicit messages within the text that may not be immediately noticeable (Neuman, 2017). The transcripts of the interviews conducted with STEM educators were transferred to Microsoft Word documents and analyzed using the QSR NVivo-11 software. Initially, descriptive codes were applied to the data, and then codes with similar characteristics were categorized into appropriate groups. After determining the codes and categories, the data were reviewed once more to ensure the accuracy of the coding and their appropriate classification under the relevant themes. After making the necessary revisions, the findings were presented in the findings section, including frequency (f) values and the pseudonyms assigned to the participants (e.g., Hasan, Kerem, Leyla, Hale, etc.).

Validity

Various measures were undertaken to ensure reliability, a crucial element in qualitative research. To assess the consistency of the analysis, the data sets of five randomly selected participants were shared with two doctoral students specializing in educational programs and instructional research, both of whom have expertise in

https://doi.org/10.33225/jbse/25.24.552

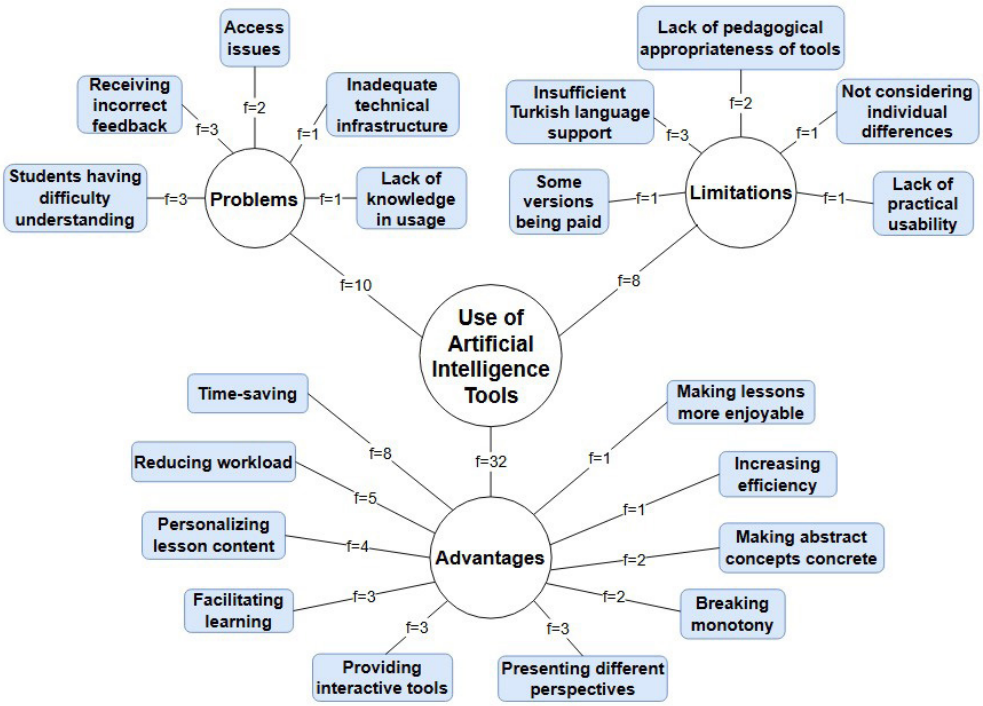
ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

qualitative data analysis. The analysis results were independently assessed by two different coders—an academic staff member and a teacher employed by the Ministry of National Education (referred to as Coder 3 and Coder 4). Intercoder reliability was calculated using Cohen's Kappa coefficient. The obtained reliability values were as follows: Kappa = .88 between Coder 1 and Coder 2, Kappa = .87 between Coder 1 and Coder 3, and Kappa = .86 between Coder 1 and Coder 4. According to Bakeman and Gottman (1997), Kappa values of .70 and above indicate a high level of reliability.

Research Results

Figure 1 illustrates the perspectives of STEM educators regarding the use of AITs in STEM-e.

Figure 1
The Use of AITs in STEM-e



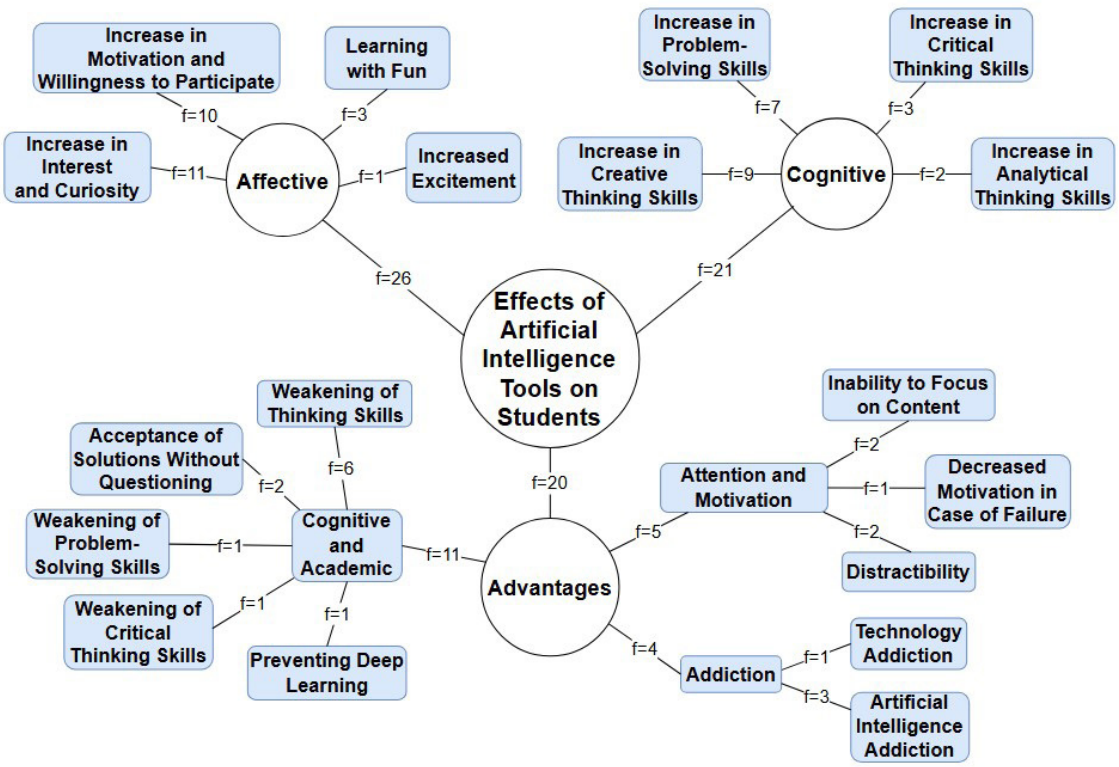
As shown in Figure 1, STEM educators recognized both the benefits and drawbacks of incorporating AITs into STEM-e. Furthermore, they highlighted various challenges faced during their implementation. Among the advantages provided by AITs in STEM-e, the teachers emphasized the factors such as saving time, reducing workload, and personalizing course content. However, they also reported that users face challenges such as lack of knowledge and access problems during the usage process. In addition, the lack of adequate support for the Turkish language was considered one of the most significant limitations of AI tools in STEM-e. Mesut, a STEM educator, emphasized that AITs save time, reduce workload, and allow for the personalization of lesson content, stating, "*With AITs, I can respond to students' needs more efficiently. Using an AI-supported application, I was able to create a customized plan tailored to each student's level. This not only reduced my workload but also better addressed students' individual needs.*" Hale underscored how AITs facilitate learning by providing interactive features and making lessons more engaging, thereby breaking the monotony of traditional instruction: "*AITs make my lessons more interactive and enjoyable. For instance, in my chemistry class, I used an AI tool that provided 3D visualizations of molecular structures. As a result, the students comprehended the topic more easily, and by the end of the lesson, a dynamic discussion emerged.*" Mert emphasized how AITs help concretize abstract concepts, making learning more accessible: "*AITs enable students to grasp lessons more easily. In a physics class, we used an AI simulation to visualize the effects of different forces. This was particularly beneficial for students who struggle with understanding abstract topics.*" Conversely, Leyla pointed out

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

that certain AITs lack pedagogical suitability: "*While attempting to use an AI-based platform during a lesson, I realized that the system was not well-suited to the dynamics of my classroom.*" Seher highlighted the challenges students face due to their lack of knowledge, stating: "*They struggle with using computers or technological devices. In particular, when working with AI-based tools, they are unsure of the steps to follow and find it difficult to navigate the process due to unfamiliar technical terms. This not only leads to a loss of time during lessons but also negatively impacts students' active participation in the learning process. Some students, when not provided with sufficient guidance, lose motivation and tend to avoid using these tools altogether.*" Kerem highlighted the limitations of AITs in terms of Turkish language support, which led to comprehension difficulties among students: "*Additionally, the students sometimes struggled to understand the content since some tools have limited Turkish language support.*" Hasan raised concerns regarding the accuracy of AI-generated feedback, noting that it occasionally misled students: "*Students received incorrect feedback on certain questions, leading them to learn misinformation even without realizing it.*" Figure 2 presents the perspectives of STEM educators on the impact of AITs on students in STEM-e.

Figure 2
The Effects of AITs on Students in STEM-e



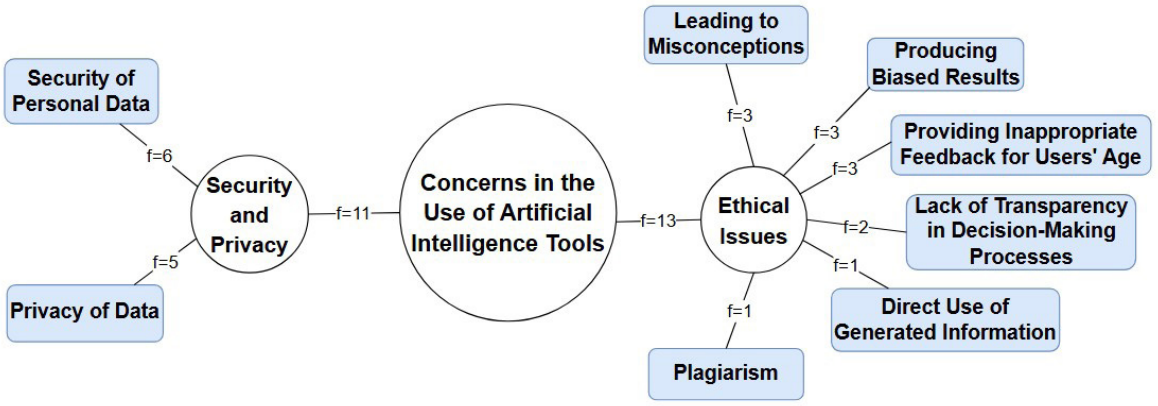
As shown in Figure 2, STEM educators recognized both cognitive and emotional benefits, as well as some negative effects, of using AITs in STEM-e. STEM educators emphasized that the use of artificial intelligence in STEM-e increases students' interest and curiosity and enhances their motivation and willingness to participate. It was also noted that students develop skills such as creativity, problem-solving, critical thinking, and analytical thinking. However, some negative effects were reported, including a decline in thinking skills, inability to focus on content, lack of attention, and dependency on artificial intelligence. Mesut emphasized that AITs are engaging, enhance motivation, and facilitate enjoyable learning, stating: "*Students find AI-based applications highly engaging. Gamified content, in particular, is extremely effective in boosting student motivation. For instance, when we used an AI-supported game application in a mathematics lesson, I noticed that students became more competitive and put in greater effort.*" Mert pointed out that AITs foster creative thinking, problem-solving, critical thinking, and analytical reasoning skills: "*AITs are truly effective in developing students' problem-solving skills. For instance, I assigned a project where students had to solve real-life problems using an AI algorithm. They first analyzed the problem, then discussed various*

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

solutions before implementing the most effective one. Throughout this process, I observed that they also enhanced their creative thinking skills." Beyza highlighted how AITs positively impact students by enhancing their curiosity and increasing their willingness to participate actively in the learning process: "*AITs have a positive effect on students. They particularly stimulate their sense of curiosity, which in turn boosts their eagerness to engage more actively in lessons. Their interest in new-generation technologies makes them more enthusiastic about exploring these tools.*" Hale, however, argued that AITs might weaken independent thinking skills: "*One student relied too much on AI, using its suggestions directly instead of developing their own solutions. This negatively affected their independent thinking.*" Teacher Leyla stated that AITs are often perceived more as entertainment, which can lead to distractions: *"Some students tend to use AITs primarily for entertainment, making it difficult for them to stay focused during lessons. For instance, when we used an AI-powered simulation in class, some students were more interested in exploring the various features of the simulation rather than engaging with the educational content. This situation disrupted the flow of the lesson and reduced the overall effectiveness of the learning process.*" Serhat highlighted the potential drawbacks of students blindly accepting AI-generated solutions: "*Some students accept the solutions provided by these tools without questioning them, which can somewhat hinder their deep learning.*" Buket expressed concerns about dependency on AITs: "*I have also observed that some students develop a dependency on AITs. In the long run, this could negatively affect their ability to solve problems independently.*" Figure 3 illustrates the concerns of STEM educators regarding the use of AITs in STEM-e.

Figure 3
Concerns Regarding the Use of AITs in STEM-e

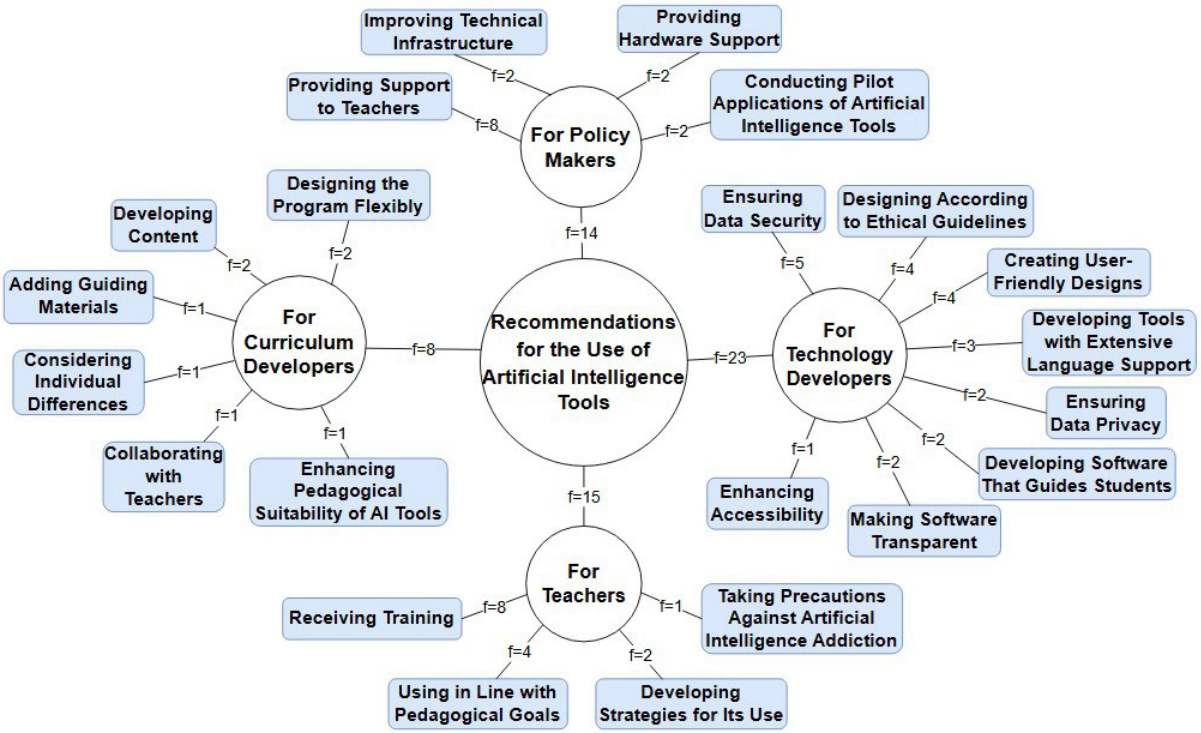


As shown in Figure 3, teachers raised concerns about the potential ethical issues and the risks related to security and privacy associated with AITs. STEM educators expressed ethical concerns regarding the use of artificial intelligence, such as the potential to lead to misconceptions, produce biased results, and provide feedback that may not be appropriate for the user's age. In addition, they also voiced concerns about the security of personal data and the privacy of information. Mehmet voiced his concerns regarding data privacy and security, stating: "*I am worried about the security of students' data. In particular, I do not have clear information on who has access to the data collected by these tools.*" Kerem pointed out that these tools could generate biased outcomes: *"I also believe that AITs can sometimes produce biased results in their decision-making processes. This could lead to unfairness among students."* Hasan emphasized the ethical challenges posed by AITs: "*Plagiarism, misinformation leading to incorrect learning, and responses that do not align with the user's profile can pose significant risks.*" Figure 4 presents the recommendations of STEM educators for the more effective use of AITs in STEM-e.

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 4
Suggestions for Enhancing the Effectiveness of AITs in STEM-e



As shown in Figure 4, STEM educators provided recommendations for enhancing the effectiveness of AITs in STEM-e, targeting teachers, policymakers, program developers, and technology creators. STEM educators stated that in order for artificial intelligence technologies to be used effectively in STEM-e, teachers need to receive training in this area and implement these tools in alignment with pedagogical goals. Additionally, it was emphasized that policymakers should provide the necessary support to teachers, curriculum developers should design flexible programs, and technology developers should create AI tools in accordance with ethical principles and with attention to data security. Teacher Kerem highlighted the necessity of training teachers on the use of AITs and ensuring their alignment with pedagogical objectives, stating, "*Before using AITs, we should receive basic training about these tools. Additionally, we need to integrate them into the teaching process in a way that aligns with pedagogical goals.*" Teacher Leyla highlighted the need to improve technological infrastructure and support teachers, expressing, "*It is essential to provide the necessary technological infrastructure in schools and support teachers in this regard.*" Teacher Mehmet pointed out that programs designed with these tools should have flexible and appropriate content, saying, "*For the effective use of AITs in education, they need to have a user-friendly and flexible design. Moreover, it is crucial to create the content required in the teaching process.*" Teacher Mesut stressed that AITs should be designed to ensure data privacy, security, and ethical standards, stating, "*The tools should focus more on ethical design and user privacy.*" Buket teacher has pointed out that pilot implementations of these tools should be conducted: "*Schools should support the pilot applications of these tools and evaluate the results. Observing how students interact with these tools at different levels will allow teachers to understand which methods are more effective. At the same time, observing how these tools work in classrooms will help identify potential shortcomings and challenges in advance.*" Hale teacher has emphasized the importance of collaboration among teachers to make these tools pedagogically appropriate: "*In order to use AITs more effectively in STEM-e, their pedagogical aspects need to be taken into consideration as well. No matter how advanced the technology is, it is essential for teachers to be involved in the process to make these tools suitable for students' learning processes. Collaborating with teachers is important to make these tools more pedagogical. Teachers are the ones who best understand students' needs in the classroom, and their feedback can help ensure that these tools are tailored to students' learning styles, speeds, and levels.*"

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Discussion

In this study, STEM educators emphasized various benefits of AITs in the teaching process, such as improved time efficiency, reduced workload, personalized content, and interactive learning resources. They also noted that AITs facilitate learning, offer diverse perspectives, break monotony, concretize abstract concepts, enhance efficiency, and make lessons more engaging. These findings are consistent with previous studies highlighting the advantages of AITs in STEM-e (Alshorman, 2024; Chassignol et al., 2018; Chen et al., 2020; Chng et al., 2023; Feser, 2024; Hashim et al., 2021; Holmes et al., 2019; Joseph & Uzondu, 2024; Luckin & Holmes, 2016; Parviz, 2024; Rane et al., 2023; Roll & Wylie, 2016; Tedre et al., 2021; Uğraş et al., 2024; Uyanik Aktulun et al., 2024; Xu & Ouyang, 2022). The literature further suggests that AITs enable customized learning in STEM-e (Chassignol et al., 2018; Chen et al., 2020; Chng et al., 2023; Hashim et al., 2021; Holmes et al., 2019; Joseph & Uzondu, 2024; Luckin & Holmes, 2016; Parviz, 2024; Rane et al., 2023; Roll & Wylie, 2016; Tedre et al., 2021; Uğraş et al., 2024), improve time efficiency (Parviz, 2024; Uğraş et al., 2024), enhance productivity (Parviz, 2024), provide interactive learning tools (Fisher & Baird, 2020; Joseph & Uzondu, 2024; Parviz, 2024; Uğraş et al., 2024), facilitate and make learning more enjoyable (Uğraş et al., 2024), help in concretizing abstract concepts (Almusaed et al., 2023; Chen et al., 2020; Chng et al., 2023; Zawacki-Richter et al., 2019), and reduce teachers' workload while increasing student engagement (Alhazmi et al., 2023). These findings largely coincide with the results obtained in this study. Additionally, prior research indicated that AITs enhance accessibility and provide instant feedback in STEM-e (Parviz, 2024; Uğraş et al., 2024), streamline the material development process (Parviz, 2024), enable the detection and analysis of student behaviors (Xu & Ouyang, 2022), improve student participation and facilitate more effective assessment of student performance (Chassignol et al., 2018; Joseph & Uzondu, 2024; Tedre et al., 2021), enhance memory retention (Fisher & Baird, 2020), and simplify the management of large classrooms (Uğraş et al., 2024). These findings suggest that the advantages of AITs in STEM-e may stem from their ability to bridge cognitive gaps, streamline instructional processes, and address individual learning needs more effectively than traditional methods. One possible explanation for these benefits is that AITs offer adaptive learning pathways, allowing students to progress at their own pace and receive targeted support, which is particularly beneficial in STEM subjects that require cumulative knowledge building. Additionally, the efficiency gains observed in AI-integrated classrooms could be attributed to automation in grading, content delivery, and feedback generation, which reduces the administrative burden on educators and allows them to focus on higher-order instructional strategies. The increased engagement and motivation facilitated by AI-driven interactive tools may result from their ability to present complex concepts in visually and contextually enriched formats, catering to diverse learning preferences and enhancing comprehension. The literature also highlights how AITs provide real-time feedback and personalized learning experiences, which may contribute to improved student outcomes. This aligns with cognitive load theory, suggesting that when students receive immediate, precise, and adaptive feedback, they can adjust their learning strategies and retain information effectively. Furthermore, the enhancement of student engagement could be linked to gamification and AI-powered simulations, which transforms abstract theories into interactive, problem-solving experiences. Another key factor underlying these findings could be the increasing alignment of AITs with constructivist pedagogical approaches. AI supports exploratory learning, helping students enhance their problem-solving and critical thinking abilities, which are essential in STEM-e. This shift towards more student-centered learning environments may also explain why AI integration leads to higher motivation and sustained interest in STEM subjects. However, while these benefits are significant, their realization is often contingent upon institutional support, teacher expertise, and the adequacy of technological infrastructure. Without proper training and pedagogical alignment, educators may struggle to fully leverage AI's potential, which underscores the importance of professional development programs that equip teachers with AI literacy and implementation strategies. In summary, the advantages of AITs in STEM-e appear to be driven by their adaptability, automation capabilities, and capacity to enhance engagement through interactive and personalized learning experiences. Nevertheless, maximizing these benefits requires addressing the existing challenges related to accessibility, pedagogical integration, and equitable resource distribution, ensuring that AI serves as an enabler rather than a barrier to effective STEM-e.

However, the study revealed several difficulties faced by STEM educators, such as lack of knowledge, accessibility issues, inaccurate feedback, inadequate technical infrastructure, and student comprehension challenges, which hindered the teaching process. Additionally, barriers to the effective integration of AITs were identified, including insufficient support for the Turkish language, limited pedagogical alignment, high costs for certain versions, lack of consideration for individual differences, and impractical usability. These findings are consistent with some of the challenges reported in the literature on the use of AITs in STEM-e. Previous studies have highlighted similar issues, including a lack of knowledge about AI applications in STEM-e (Joseph & Uzondu, 2024), deficiencies in technical

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

infrastructure (Zawacki-Richter et al., 2019; Whittaker et al., 2018), and inaccurate feedback (Shaikh et al., 2022; Vial, 2019; Viloria et al., 2019; Vinge, 2013; Yılmaz, 2024). However, some studies suggest that AITs might make the digital gap worse by limiting access to AI and machine learning tools for students in schools with fewer resources. Furthermore, studies have found that using AI in education can reduce the teacher's role, decrease human interaction, cause digital tiredness, make classroom management harder, and raise concerns about how students are assessed. These issues can make it difficult to use AITs effectively in education (Joseph & Uzondu, 2024; Moore, 2022; Shaikh et al., 2022; Vial, 2019; Viloria et al., 2019; Vinge, 2013; Yılmaz, 2024).

STEM educators' challenges in using AITs may stem from the rapid pace of technological advancement, which often outpaces professional development opportunities for teachers. The lack of knowledge about AI applications may result from insufficient training programs and limited access to hands-on experiences with these tools. Without sufficient support, educators may face challenges in effectively incorporating AI into their teaching methods. Additionally, accessibility issues and inadequate technical infrastructure might be linked to educational funding disparities, particularly in under-resourced schools where outdated devices and unreliable internet connections hinder the seamless use of AI-powered learning tools. The problem of getting accurate feedback from AITs may be caused by the limits of today's AI models, which often have trouble understanding context, cultural differences, and complex subject areas. This issue becomes even more pronounced when AITs lack strong support for the Turkish language, as many algorithms are primarily trained on English-language datasets. As a result, these tools may fail to provide precise, contextually relevant feedback to students and educators. Pedagogical misalignment and the failure to accommodate individual differences suggest that AITs are still largely designed with a one-size-fits-all approach rather than being tailored to diverse learning styles. Many AI-driven platforms prioritize efficiency and automation over adaptability, making it difficult for students with unique learning needs to fully benefit from their capabilities (Ayeni et al., 2024). Some AITs are costly, which may prevent many schools—especially public ones with limited budgets—from using them widely. Another key problem is the changing role of teachers in AI-supported classrooms. Although AITs can improve learning, their effectiveness depends on how well they are integrated with traditional teaching. Concerns about reduced teacher-student interaction and digital fatigue show the need for a balanced use of AI—as a support, not a replacement for teachers. These challenges also point to the importance of cooperation between educators, policymakers, and AI developers.

Interviews with STEM educators revealed that AITs provide various cognitive and affective benefits to students in STEM-e. Educators emphasized that AITs enhance students' interest and motivation, making the learning process more engaging, increasing their willingness to participate actively, and fostering their sense of curiosity. From a cognitive perspective, these tools were recognized for their contribution to the development of creative thinking, problem-solving, critical thinking, and analytical reasoning skills. These results are consistent with previous studies in the literature that highlight the advantages of AI-supported STEM-e for students. Earlier research has shown that AITs promote active student engagement in the learning process (Parviz, 2024), increase their interest (Chen et al., 2020; Uğraş et al., 2024), and boost their motivation (Ashri, 2020; Berendt et al., 2020; Borenstein & Howard, 2021; Chen et al., 2020; Parviz, 2024; Uğraş et al., 2024; Yılmaz, 2024), while also sparking their curiosity (Uğraş et al., 2024). Moreover, AITs have been found to enhance students' problem-solving abilities (Bayram & Çelik, 2023; Xu & Ouyang, 2022), promote creative thinking (Bayram & Çelik, 2023), and improve both critical (Bayram & Çelik, 2023; Joseph & Uzondu, 2024) and analytical thinking skills (Bayram & Çelik, 2023). However, the study also revealed that STEM educators are worried about the potential negative impacts of excessive or uncritical use of AITs on students. Specifically, they pointed out risks such as the weakening of cognitive skills, the tendency to accept solutions without questioning, and a decline in problem-solving and critical thinking skills. Additionally, negative affective consequences, including difficulties in focusing on content, increased distractibility, and loss of motivation in the face of failure, were observed. Moreover, educators emphasized the risk of AI and technology addiction, stressing the importance of using these tools in a balanced and pedagogically conscious manner. Likewise, the literature acknowledges that the use of AITs in STEM-e may lead to certain negative outcomes for students. Previous studies reported that excessive reliance on such tools can lead to technology addiction, exacerbate digital fatigue, and diminish both student-student and student-teacher interactions, thereby disrupting classroom dynamics (Ashri, 2020; Berendt, Littlejohn & Blakemore, 2020; Borenstein & Howard, 2021; Uğraş et al., 2024; Yılmaz, 2024). The cognitive and affective benefits of AITs in STEM-e can be attributed to their ability to create an interactive, adaptive, and engaging learning environment. AI-driven platforms provide immediate feedback, personalized learning paths, and real-time adaptations based on students' performance, which can naturally enhance motivation and curiosity. The increase in student engagement may stem from the fact that AITs reduce the cognitive load associated with traditional instruction by simplifying complex topics and presenting information in a more accessible manner. Additionally, the gamification elements often embedded

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

in AI-supported learning environments can stimulate students' intrinsic motivation and foster a sense of achievement. On the cognitive side, the enhancement of problem-solving, creative thinking, and analytical reasoning skills may be linked to AI's capacity to provide students with diverse scenarios and challenges that encourage exploration and experimentation. AI-powered simulations and adaptive learning systems expose students to real-world applications of STEM concepts, fostering deeper learning and retention. Additionally, by allowing students to explore various perspectives and solutions, AITs aid in the development of critical thinking skills. However, the success of AI in fostering these skills depends on its integration into the learning process—specifically, whether it encourages active engagement with the content or simply leads to passive consumption of information. Conversely, the concerns regarding AITs leading to a decline in cognitive skills and fostering over-reliance on technology may be explained by the automation of problem-solving processes. When students are frequently presented with AI-generated solutions without being required to analyze or construct their own answers, they may develop a habit of accepting information passively rather than engaging in deeper inquiry. This aligns with cognitive load theory, which suggests that excessively minimizing cognitive effort can hinder the development of independent thinking and problem-solving skills. Similarly, the affective drawbacks, such as increased distractibility and decreased motivation when faced with failure, may be tied to the instant gratification provided by AITs. If students become accustomed to immediate solutions and seamless learning experiences, they might struggle with frustration, tolerance, and perseverance when confronted with more complex challenges. Additionally, AI-driven educational tools often involve screen-based learning, which can contribute to digital fatigue and reduce attention spans over time. Finally, the risk of technology addiction can be linked to the engaging and immersive nature of AI applications, particularly when they incorporate gamification, adaptive challenges, and personalized content. The continuous stimulation provided by AI-driven learning environments may inadvertently create dependency, making it difficult for students to engage in traditional, less-interactive forms of learning. This highlights the need for careful pedagogical design to ensure that AI enhances, rather than replaces, critical thinking and problem-solving tasks in STEM-e.

The study also highlighted STEM educators' concerns about the ethical and security issues related to the use of AITs in STEM-e. Educators expressed that these tools could potentially lead to misinformation, produce biased outcomes, and create a lack of transparency in decision-making processes. Additionally, they raised ethical concerns regarding inappropriate feedback for students' age levels, the risk of direct use of AI-generated content, and potential plagiarism. Another major concern expressed by educators is data privacy and security. Similarly, the literature frequently emphasizes ethical and security risks associated with AITs. Several studies identified significant risks, particularly in terms of data privacy and security (Alshorman, 2024; Hwang et al., 2020; Joseph & Uzondu, 2024; Karafil & Uyar, 2025; Khan et al., 2023; Parviz, 2024; Uğraş et al., 2024; Yılmaz, 2024). Regan and Jesse (2019) stressed that the ethical use of student data is a critical issue and warned that improperly managed AI technologies could lead to discrimination and student profiling risks. Moreover, bias in AI and machine learning systems is recognized as a significant ethical problem. In this context, it is argued that AI systems have to be designed neutrally and fairly; otherwise, they may reinforce existing educational inequalities (Berendt et al., 2020; Joseph & Uzondu, 2024). The ethical concerns identified in this study, as well as those found in the literature, largely stem from the structural limitations of AI technologies and the biases within the datasets they rely on. The lack of transparency in AI decision-making creates distrust among educators, especially in STEM-e, where algorithmic systems are often too complex to fully understand. This uncertainty makes teachers cautious, fearing misinformation or misuse. Data privacy is another major concern. Since AITs collect and store large amounts of student data—often on cloud-based platforms—they become vulnerable to cyber threats. The absence of clear data protection policies adds to this risk, raising serious questions about student safety. Another issue is equity. If AI systems are trained on biased or incomplete data, they may reinforce existing inequalities in education. Students from disadvantaged backgrounds may have limited access to AI tools, widening the digital divide.In short, while AITs bring many advantages to STEM-e, ethical and security risks must not be overlooked. Stronger policies on transparency, data protection, and accountability are essential to ensure the fair and responsible use of AI in schools.

STEM educators provided several recommendations for the effective and efficient use of AITs in STEM-e. They stressed the importance of training teachers to use AITs in alignment with pedagogical goals, developing strategies for their use, and implementing measures to prevent AI dependency. On the other hand, they think policymakers should support teachers, improve technical infrastructure, provide hardware support, and conduct pilot implementations of AITs to facilitate their integration into educational settings. Additionally, program developers were suggested to design flexible programs, develop content, incorporate guiding materials, consider individual differences, and collaborate with teachers to make AITs more pedagogically sound. For technology developers, recommendations included ensuring data security, designing AI systems in compliance with ethical guidelines, developing user-friendly

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

tools with extensive language support, protecting data privacy, creating AI-based guidance software for students, increasing transparency in AI applications, and enhancing accessibility. Educators stressed the need for all stakeholders to collaborate in integrating AITs into STEM-e more effectively and securely. Likewise, the literature highlights the necessity of providing additional training to educators (Akgun & Greenhow, 2022; Alshorman, 2024; Parviz, 2024; Pedro et al., 2019) and maintaining pedagogical standards (Alshorman, 2024) to facilitate the integration of AI in STEM-e. Furthermore, studies underscore the importance of designing AITs in compliance with data security and privacy regulations (Alshorman, 2024; Chen et al., 2021; Joseph & Uzondu, 2024) and establishing robust data protection protocols to safeguard student information (Borenstein & Howard, 2021; Pardo & Siemens, 2014). Enhancing technical infrastructure (Uskov et al., 2018), creating user-friendly designs (Amershi et al., 2019), and ensuring transparency in AI decision-making processes (Floridi, 2019) are also regarded as essential aspects of this process. Moreover, reports indicate that policymakers, program developers, technology developers, and educators should collaborate to create pedagogically sound, effective, inclusive, and equitable AITs while avoiding biases and inequalities (Berendt et al., 2020; Chen et al., 2021; Joseph & Uzondu, 2024; Kent et al., 2019; Long & Magerko, 2020). These findings align with our study's results, emphasizing that integrating AI into STEM-e is a multifaceted process that can be improved through the joint efforts of all involved parties. However, some studies emphasize different aspects of AI integration in education. For instance, Feser (2024) argues that teachers should use AITs while adhering to the curriculum and that integrating AI into high school STEM curricula should be a fundamental part of educational planning. Additionally, there is a growing need for specialized training on effectively integrating AI into teaching practices (Luckin & Holmes, 2016; Parviz, 2024; Xu & Ouyang, 2022). The importance of educating students about the ethical implications of AI and machine learning is also emphasized, as these technologies are expected to affect multiple aspects of students' lives and careers (Berendt et al., 2020). Regarding the adoption of AI solutions in education, some studies suggest that schools and educational institutions could benefit from collaborations with technology companies, which can provide the necessary expertise and resources (Joseph & Uzondu, 2024). Other studies offer alternative perspectives on AI integration in STEM-e. For example, Uğraş et al. (2024) stress the need to educate parents and school administrators about AITs, particularly ChatGPT. These varied perspectives demonstrate that the integration of AITs into STEM-e is a multifaceted process that requires cooperation across several domains. The reasons behind these findings can be attributed to several key factors. First, the necessity of teacher training in AITs stems from the rapid advancements in technology, which often outpace traditional pedagogical methods. Without sufficient training, teachers may struggle to integrate AI into their lessons in a way that improves learning outcomes, rather than just automating tasks. There are also concerns about students becoming overly dependent on AI, as excessive reliance on AI-driven tools could reduce their cognitive engagement, problem-solving skills, and independent critical thinking abilities. This concern is supported by previous research, which highlights that the overuse of AITs can lead to passive learning behaviors and diminished intellectual effort. Moreover, the focus on technical infrastructure and accessibility underscores the reality that many educational institutions lack the necessary resources to effectively implement AI. Schools in underprivileged regions may face challenges in obtaining advanced hardware, stable internet connections, and necessary software, exacerbating the digital divide. The emphasis on data security and ethical compliance underscores the increasing concern over privacy issues, particularly due to the large volumes of student data being processed by AI systems. If AITs are not designed with transparent data protection mechanisms, they could expose students to risks such as data breaches, algorithmic bias, and unethical data usage. Furthermore, the necessity for collaboration among policymakers, program developers, and educators stems from the understanding that AI integration in STEM-e is not merely a technological change but also a shift in pedagogical practices. When these stakeholders work in isolation, AITs may lack alignment with educational goals, leading to ineffective implementation. Previous research supports this, showing that interdisciplinary collaboration enhances the pedagogical soundness and inclusivity of AI-driven educational solutions. Furthermore, the call for parent and administrator education on AITs underscores the role of broader educational communities in fostering responsible AI use. If parents and administrators are not fully informed about the benefits and risks of AI, misunderstandings and resistance may obstruct its successful integration.

Conclusions and Implications

This study emphasized both the advantages and challenges of using AITs in STEM-e and provided recommendations for their successful integration into educational practices. The findings showed that STEM educators view AITs as advantageous in several areas, including time-saving, personalizing lesson content, facilitating learning, and boosting student motivation. However, the study also highlighted several challenges in the implementation of AITs, such as concerns regarding pedagogical suitability, accessibility issues, inaccurate feedback, inadequate

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

technical infrastructure, and limited language support. The research highlighted that a balanced and conscious use of AITs contributes to students' cognitive and affective development. However, the excessive or unregulated use of AITs may result in a decrease in problem-solving and critical thinking skills.

The study recommended that AITs be implemented in educational settings in a secure, ethical, and pedagogically sound manner. It suggests that teachers should receive proper training to effectively utilize AITs, develop strategies aligned with pedagogical goals, and take steps to prevent technology addiction. Policymakers and educational institutions should improve technical infrastructure, support teachers, and initiate pilot programs to facilitate the integration of AITs into the educational process. Furthermore, technology developers should focus on data security, ethical design principles, and user-friendly interfaces to ensure these tools are more accessible and effective.

Fully realizing the potential of AITs in STEM-e necessitates cooperation among teachers, students, policymakers, and technology developers. STEM teachers need to participate in in-service training programs and become aware of how to effectively integrate these tools into lesson plans that align with pedagogical objectives. Since students' learning rates and needs may vary, AI-supported learning processes should be planned flexibly and personalized. Moreover, considering that AITs may produce biased results and lead to data privacy concerns, teachers need to choose reliable platforms that adhere to ethical standards. Future studies should explore the long-term effects of integrating AITs into education, particularly in relation to students' academic achievement, cognitive development, and learning motivation. Additionally, there is a need to create guiding frameworks for the effective integration of these technologies in education and to assess their effectiveness. The success of AI-supported educational processes will rely not only on the technology's capabilities but also on its intentional, balanced, and pedagogically informed use. In this regard, active participation from all stakeholders in the education system, continual updates to the role of AITs through dynamic strategies, and improvements in technical infrastructure within schools to ensure teachers have access to these technologies will enhance the effectiveness of educational processes.

References

Akgün, S., & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. *AI and Ethics, 2*(3), 431–440. https://doi.org/10.1007/s43681-021-00096-7

Aktulun, O. U., Kasapoğlu, K., & Aydoğdu, B. (2024). Comparing Turkish pre-service STEM and non-STEM teachers' attitudes and anxiety toward artificial intelligence. *Journal of Baltic Science Education, 23*(5), 950–963. https://doi.org/10.33225/jbse/24.23.950

Alhazmi, A. K., Alhammadi, F., Zain, A. A., Kaed, E., & Ahmed, B. (2023). AI's role and application in education: Systematic review. *Intelligent Sustainable Systems: Selected Papers of WorldS4 2022, 1*, 1–14. https://doi.org/10.1007/978-981-19-7660-5_1

Almusaed, A., Almssad, A., Yitmen, I., & Homod, R. Z. (2023). Enhancing student engagement: Harnessing AIED's power in hybrid education—A review analysis. *Education Sciences, 13*(7), Article 632. https://doi.org/10.3390/educsci13070632

Alshorman, S. M. (2024). The readiness to use AI in teaching science: Science teachers' perspective. *Journal of Baltic Science Education, 23*(3), 432–448. https://doi.org/10.33225/jbse/24.23.432

Amershi, S., Weld, D., Vorvoreanu, M., Fourney, A., Nushi, B., Collisson, P., Suh, J., Iqbal, S., Bennett, P. N., Inkpen, K., & Teevan, J. (2019). Guidelines for human-AI interaction. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1–13). ACM. https://doi.org/10.1145/3290605.3300233

Ashri, R. (2020). *The AI-powered workplace: How artificial intelligence, data, and messaging platforms are defining the future of work*. Apress.

Ay, K., & Seferoğlu, S. S. (2021). An investigation on various countries' STEM education policies and implications for Turkey. *Erzincan University Journal of Education Faculty, 23*(1), 82–105. https://doi.org/10.17556/erziefd. 669988

Ayeni, A. O., Ovbiye, R. E., Onayemi, A. S., & Ojedele, K. E. (2024). AI-driven adaptive learning platforms: Enhancing educational outcomes for students with special needs through user-centric, tailored digital tools. *World Journal of Advanced Research and Reviews, 22*(3), 2253–2265. https://doi.org/10.30574/wjarr.2024.22.3.0843

Bahrami, M. R., Bahrami, B., Behboodi, F., & Pourrafe, S. (2023). Teaching the future: The vision of AI/ChatGPT in education. In G. Jezic, J. Chen-Burger, M. Kusek, R. Sperka, R. J. Howlett, & L. C. Jain (Eds.), *Agents and multi-agent systems: Technologies and applications 2023* (Vol. 354, pp. 393–402). Springer Nature. https://doi.org/10.1007/978-981-99-3068-5_37

Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis.* Cambridge University Press.

Bayram, K., & Çelik, H. (2023). Yapay zekâ konusunda muhakeme ve girişimcilik becerileriyle bütünleştirilmiş sosyo-bilim etkinliği: Fen bilgisi öğretmen adaylarının görüşleri [A socio-scientific activity integrated with reasoning and entrepreneurship skills on artificial intelligence: The views of pre-service science teachers]. *Fen Bilimleri Öğretimi Dergisi, 11*(1), 41–78. https://doi.org/10.56423/fbod.1241946

Berendt, B., Littlejohn, A., & Blakemore, M. (2020). AI in education: Learner choice and fundamental rights. *Learning, Media and Technology, 45*(3), 312–324. https://doi.org/10.1080/17439884.2020.1786396

Borenstein, J., & Howard, A. (2021). Emerging challenges in AI and the need for AI ethics education. *AI and Ethics, 1*(1), 61–65. https://doi.org/10.1007/s43681-020-00002-7

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş., & Demirel, F. (2020). *Bilimsel araştırma yöntemleri* [Scientific research methods] (28. baskı). Pegem Akademi.

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Chassignol, M., Khoroshavin, A., Klimova, A., & Bilyatdinova, A. (2018). Artificial intelligence trends in education: A narrative overview. *Procedia Computer Science, 136*, 16–24. https://doi.org/10.1016/j.procs.2018.08.233

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access, 8*, 75264–75278. https://doi.org/10.1109/ACCESS.2020.2988510

Chng, E., Tan, A. L., & Tan, S. C. (2023). Examining the use of emerging technologies in schools: A review of artificial intelligence and immersive technologies in STEM education. *Journal for STEM Education Research, 6*(3), 385–407. https://doi.org/10.1007/s41979-023-00092-y

Feser, M. S. (2024). Parents' views on the use of AI-based chatbots such as ChatGPT in high school (STEM) education. *Journal of Baltic Science Education, 23*(1), 4–8. https://doi.org/10.33225/jbse/24.23.04

Fisher, M. M., & Baird, D. E. (2020). Humanizing user experience design strategies with new technologies: AR, VR, MR, Zoom, Ally, and AI to support student engagement and retention in higher education. In S. S. H. (Ed.), *International perspectives on the role of technology in humanizing higher education* (pp. 105–129). Emerald Publishing. https://doi.org/10.1108/S2055-364120200000033007

Floridi, L. (2019). Translating principles into practices of digital ethics: Five risks of being unethical. *Philosophy & Technology, 32*(2), 185–193. https://doi.org/10.1007/s13347-019-00354-x

Gökçe-Tekin, Ö., Şan, İ., & Orhan-Karsak, H. G. (2023). Ortaokul ve lise öğrencilerinin STEM öz-yeterlik algı düzeyi [STEM self-efficacy perceptions of middle and high school students]. *Turkish Educational Sciences Journal (TEBD)*, *21*(1), 235–259. https://doi.org/10.37217/tebd.1177086

Hashim, S., Omar, M. K., Ab Jalil, H., & Sharef, N. M. (2022). Trends on technologies and artificial intelligence in education for personalized learning: Systematic literature review. *Journal of Academic Research in Progressive Education and Development, 12*(1), 884–903. http://dx.doi.org/10.6007/IJARPED/v11-i1/12230

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning.* Center for Curriculum Redesign. https://curriculumredesign.org/wp-content/uploads/AIED-Book-Excerpt-CCR.pdf

Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 1*, Article 100001. https://doi.org/10.1016/j.caeai.2020.100001

Joseph, O. B., & Uzondu, N. C. (2024). Integrating AI and machine learning in STEM education: Challenges and opportunities. *Computer Science & IT Research Journal, 5*(8), 1732–1750. https://doi.org/10.51594/csitrj.v5i8.1379

Karafil, B., & Uyar, A. (2025). Exploring knowledge, attitudes, and practices of academics in the field of educational sciences towards using ChatGPT. *Education and Information Technologies.* https://doi.org/10.1007/s10639-024-13291-w

Karaman, M. R., & Goksu, I. (2024). Are lesson plans created by ChatGPT more effective? An experimental study. *International Journal of Technology in Education, 7*(1), 107–127. https://doi.org/10.46328/ijte.607

Kennedy, M. J., Thomas, C. N., Aronin, S., Newton, J. R., & Lloyd, J. W. (2014). Improving teacher candidate knowledge using content acquisition podcasts. *Computers & Education, 70*, 116–127. https://doi.org/10.1016/j.compedu.2013.08.010

Kent, C., Rechavi, A., & Rafaeli, S. (2019). Networked learning analytics: A theoretically informed methodology for analytics of collaborative learning. In *Learning in a networked society: Spontaneous and designed technology enhanced learning communities* (pp. 145–175). Springer. https://doi.org/10.1007/978-3-030-14610-8_9

Khan, F. A., Li, G., Khan, A. N., Khan, Q. W., Hadjouni, M., & Elmannai, H. (2023). AI-driven counter-terrorism: Enhancing global security through advanced predictive analytics. *IEEE Access, 11*, 135864–135879. https://doi.org/10.1109/ACCESS.2023.3336811

Kim, J. (2023). Leading teachers' perspective on teacher-AI collaboration in education. *Education and Information Technologies.* https://doi.org/10.1007/s10639-023-12109-5

Kim, J., Lee, H., & Cho, Y. H. (2022). Learning design to support student-AI collaboration: Perspectives of leading teachers for AI in education. *Education and Information Technologies, 27*(5), 6069–6104. https://doi.org/10.1007/s10639-021-10831-6

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1–16). https://doi.org/10.1145/3313831.3376727

Luckin, R., & Holmes, W. (2016). *Intelligence unleashed: An argument for AI in education*. UCL Knowledge Lab. https://discovery.ucl.ac.uk/id/eprint/1475756/

Neuman, L. W. (2017). *Social research methods: Qualitative and quantitative approaches* (Özge, S., Trans.). Yayın Odası.

Pardo, A., & Siemens, G. (2014). Ethical and privacy principles for learning analytics. *British Journal of Educational Technology, 45*(3), 438–450. https://doi.org/10.1111/bjet.12152

Parviz, M. (2024). AI in education: Comparative perspectives from STEM and non-STEM instructors. *Computers and Education Open, 6*, 100190. https://doi.org/10.1016/j.caeo.2024.100190

Patton, M. Q. (2005). *Qualitative research and evaluation methods.* Sage Publications.

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development.* https://hdl.handle.net/20.500.12799/6533

Rane, N., Choudhary, S., & Rane, J. (2023). Education 4.0 and 5.0: Integrating artificial intelligence (AI) for personalized and adaptive learning. *SSRN Electronic Journal.* https://doi.org/10.2139/ssrn.4638365

Regan, P. M., & Jesse, J. (2019). Ethical challenges of EdTech, big data, and personalized learning: Twenty-first century student sorting and tracking. *Ethics and Information Technology, 21*, 167–179. https://doi.org/10.1007/s10676-019-09513-5

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

Shaikh, A. A., Kumar, A., Jani, K., Mitra, S., García-Tadeo, D. A., & Devarajan, A. (2022). The role of machine learning and artificial intelligence for making a digital classroom and its sustainable impact on education during COVID-19. *Materials Today: Proceedings, 56*, 3211–3215. https://doi.org/10.1016/j.matpr.2021.09.368

https://doi.org/10.33225/jbse/25.24.552

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Smith-Mutegi, D., Mamo, Y., Kim, J., Crompton, H., & McConnell, M. (2025). Perceptions of STEM education and artificial intelligence: A Twitter (X) sentiment analysis. *International Journal of STEM Education, 12*(1), 1–18. https://doi.org/10.1186/s40594-025-00527-5

Tatineni, S. (2019). Ethical considerations in AI and data science: Bias, fairness, and accountability. *International Journal of Information Technology and Management Information Systems, 10*(1), 11–21. https://iaeme.com/Home/issue/IJITMIS?Volume=10&Issue=1

Tedre, M., Toivonen, T., Kahila, J., Vartiainen, H., Valtonen, T., Jormanainen, I., & Pears, A. (2021). Teaching machine learning in K–12 classroom: Pedagogical and technological trajectories for artificial intelligence education. *IEEE Access, 9*, 110558–110572. https://doi.org/10.1109/ACCESS.2021.3097962

Uğraş, H., Uğraş, M., Papadakis, S., & Kalogiannakis, M. (2024). Innovative early childhood STEM education with ChatGPT: Teacher perspectives. *Technology, Knowledge and Learning*, 1–23. https://doi.org/10.1007/s10758-024-09804-8

Uskov, V. L., Bakken, J. P., Penumatsa, A., Heinemann, C., & Rachakonda, R. (2018). Smart pedagogy for smart universities. In *Smart Education and e-Learning 2017* (Vol. 4, pp. 3–16). Springer International Publishing. https://doi.org/10.1007/978-3-319-59451-4_1

Van Den Berg, G., & du Plessis, E. (2023). ChatGPT and generative AI: Possibilities for its contribution to lesson planning, critical thinking and openness in teacher education. *Education Sciences, 13*(10), 998. https://doi.org/10.3390/educsci13100998

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *Journal of Strategic Information Systems, 28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Viloria, A., López, J. R., Payares, K., Vargas-Mercado, C., Duran, S. E., Hernández-Palma, H., & David, M. A. (2019). Determining student interactions in a virtual learning environment using data mining. *Procedia Computer Science, 155*, 587–592. https://doi.org/10.1016/j.procs.2019.08.082

Vincent-Lancrin, S., & Van der Vlies, R. (2020). Trustworthy artificial intelligence (AI) in education: Promises and challenges. https://doi.org/10.1787/19939019

Vinge, V. (2013). Technological singularity. In M. More & N. Vita-More (Eds.), *The transhumanist reader* (pp. 365–375). Wiley-Blackwell.

Whittaker, M., Crawford, K., Dobbe, R., Fried, G., Kaziunas, E., Mathur, V., West, S. M., Richardson, R., Schultz, J., & Schwartz, O. (2018). *AI Now Report 2018* (pp. 1–62). AI Now Institute at New York University.

Wu, T., He, S., Liu, J., Sun, S., Liu, K., Han, Q. L., & Tang, Y. (2023). A brief overview of ChatGPT: The history, status quo and potential future development. *IEEE/CAA Journal of Automatica Sinica, 10*(5), 1122–1136. https://doi.org/10.1109/JAS.2023.123618

Xu, W., & Ouyang, F. (2022). The application of AI technologies in STEM education: A systematic review from 2011 to 2021. *International Journal of STEM Education, 9*(1), 59. https://doi.org/10.1186/s40594-022-00377-5

Yıldırım, A., & Şimşek, H. (2018). *Sosyal bilimlerde nitel araştırma yöntemleri* [Qualitative research methods in the social sciences] (11. baskı). Seçkin Yayıncılık.

Yılmaz, A. (2024). Öğretmenlerin fen eğitiminde yapay zekâ, transhümanizm ve yaratıcılık uygulamalarını kullanmalarının güçlü ve zayıf yönleri [Strengths and weaknesses of teachers' use of artificial intelligence, transhumanism, and creativity practices in science education]. *International Journal of Eurasia Social Sciences (IJOESS), 15*(55), 17–36. http://dx.doi.org/10.35826/ijoess.4448

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – Where are the educators? *International Journal of Educational Technology in Higher Education, 16*(1), 1–27. https://doi.org/10.1186/s41239-019-0171-0

Received: *March 16, 2025* Revised: *April 15, 2025* Accepted: *May 21, 2025*

Cite as: Uyar, A. (2025). Effective use of artificial intelligence tools in stem education: Perspectives of STEM educators. *Journal of Baltic Science Education*, *24*(3), 552–566. https://doi.org/10.33225/jbse/25.24.552

Ahmet Uyar PhD, Assistant Professor, Department of Computer Technologies, Antakya Vocational School, Hatay Mustafa Kemal University Antakya, Hatay Türkiye.
E-mail: ahmet_uyar23@hotmail.com
ORCID: https://orcid.org/0000-0001-9694-8629