

# Integration of Artificial Intelligence in STEM Education to Enhance Problem Solving and Critical Thinking skills

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## Research Article

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Integration of Artificial Intelligence in STEM Education to Enhance Problem  
Solving and Critical Thinking skills

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## **Abstract**

The integration of Artificial Intelligence (AI) into Science, Technology, Engineering, and Mathematics (STEM) education has substantially reshaped teaching and learning practices by fostering students' problem-solving and critical-thinking skills. AI-powered tools and platforms can provide personalized learning experiences, accommodate learners' diverse needs, and promote active engagement with complex scientific concepts. This study investigates the perceptions of secondary science teachers in the Asir district regarding the role of integrating AI into STEM education in enhancing students' problem-solving and critical-thinking skills. A mixed-methods approach was employed. Quantitative data were collected from 180 teachers using a Likert-scale questionnaire, while qualitative data were obtained through interviews with 12 participants. The data were analyzed using descriptive statistics, correlation analyses, and independent-samples t-tests. The findings indicated that science teachers held positive perceptions toward the integration of AI in STEM education. The results also revealed no statistically significant differences in participants' perceptions attributable to gender. The study concludes with implications for science teacher professional development and recommendations for future research.

**Keywords:** Artificial Intelligence, STEM Education, Problem-Solving, Critical Thinking,

## **Introduction**

The rapid development of Artificial Intelligence (AI) has generated substantial transformations across many sectors, particularly education. Within Science, Technology, Engineering, and Mathematics (STEM) education, AI has emerged as a transformative force that can reshape instructional practices and improve learning outcomes. AI-supported tools, intelligent learning systems, and data-driven instructional approaches can promote students' problem-solving and critical-thinking skills by providing personalized learning experiences that respond to their diverse needs and learning patterns (Luckin, 2017; Bower, 2019). As technological capabilities continue to advance, educational institutions have increasingly adopted AI-based applications to develop adaptive learning environments that support individualized instruction and facilitate more effective knowledge acquisition (Holmes et al., 2019; Cukurova et al., 2019).

Artificial Intelligence has therefore become an increasingly important component of contemporary educational systems, especially in STEM disciplines. AI technologies offer considerable potential to transform conventional teaching methods and learning processes by enabling more flexible, interactive, and learner-centered educational experiences (Chiu & Li, 2023; Xu & Ouyang, 2023). Previous research has emphasized the value of AI applications in improving educational practices and supporting meaningful learning experiences across different educational contexts (Li et al., 2024; Chiu & Fujita, 2019). In STEM education, AI can provide learners and teachers with a range of opportunities to enhance the effectiveness of teaching and learning processes, including the delivery of customized content that aligns with students' individual abilities, needs, and preferences (Lee & Kwon, 2024; Raj & Khare, 2021).

Artificial intelligence technologies also enable teachers to analyze students' academic performance, identify learning difficulties, and make instructional decisions based on data-driven evidence. Such capabilities can assist teachers in designing appropriate teaching strategies and

interventions that address students' learning needs more effectively (Kim & Kim, 2022; Fisher, 2018; Hammond, 2019). In addition, AI can enrich learning experiences by presenting complex scientific concepts in more accessible and understandable forms, thereby supporting students' comprehension and engagement with challenging content (Jeon et al., 2024; Heffernan & Heffernan, 2018). In the context of STEM education, AI may contribute to improving the quality of instruction and developing students' scientific thinking skills through more dynamic, interactive, and engaging learning activities (Li & Zhong, 2024; Ferguson et al., 2020).

The integration of AI into STEM education has also encouraged innovation in instructional practices. Teachers can use AI-supported tools to increase students' interest in scientific subjects, improve their scientific literacy, and create learning environments that are more responsive to individual differences (Kim & Kim, 2022; Greller & Drachsler, 2020; Suen, 2018). AI can further support students' motivation to learn by providing personalized instruction, immediate feedback, and adaptive learning pathways that accommodate different learning preferences and levels of readiness (Al Nabhani et al., 2025). These personalized experiences may strengthen students' engagement, stimulate their interest in STEM learning, and enhance their academic motivation (Khurma et al., 2024; Wouters & Van Oostendorp, 2019; Lee & Kwon, 2024; Wilson & McMahon, 2020; Suthers, 2019). Moreover, the expanding capabilities of AI enable teachers to keep pace with developments in science education and continuously improve their instructional practices.

Despite the growing importance of AI in education, research examining its role and impact within STEM learning contexts remains relatively limited. Existing studies have primarily focused on the potential of AI to support learning, increase motivation, and develop students' technological awareness. For example, Lee and Kwon (2024) examined the integration of AI into primary and secondary education by reviewing 25 studies published between 2018 and 2023. Their findings

indicated that AI education can contribute to the development of students' AI awareness, problem-solving skills, ethical understanding, motivation, and positive attitudes toward technology. The study also showed that AI-supported learning experiences may increase students' interest in technology-related fields and strengthen their future career aspirations.

One of the most important contributions of AI to STEM education lies in its potential to enhance students' problem-solving abilities. AI-powered educational platforms, including virtual laboratories and intelligent tutoring systems, can provide immediate feedback that supports students in identifying errors, improving their understanding, and developing systematic strategies for solving complex problems in STEM disciplines (Zawacki-Richter et al., 2019; Yang & Liu, 2021). These systems use machine-learning algorithms to analyze learners' performance and adapt instructional content accordingly, resulting in personalized learning experiences that promote both engagement and deeper comprehension (Kumar et al., 2020; Yoon et al., 2020). AI-supported simulations also provide students with opportunities to explore scientific concepts in interactive and low-risk environments, which may enhance their analytical thinking, deductive reasoning, and ability to apply knowledge in problem-solving situations (Molnar, 2020).

Nevertheless, the integration of AI into STEM education presents several challenges that require careful consideration. Ethical issues, data privacy concerns, and algorithmic bias raise important questions about the protection of students' information and the equitable availability of AI-supported educational opportunities (Williamson & Eynon, 2020). In addition, the successful implementation of AI technologies in educational settings depends on adequate teacher preparation, professional development, and sustained institutional support. Teachers need the knowledge and skills necessary to use AI tools effectively and responsibly in ways that enhance student learning outcomes (Selwyn, 2019; Siemens & Long, 2020). Aoun (2017) further

emphasized the importance of maintaining a balanced relationship between traditional pedagogical approaches and technological support, while recognizing the continuing role of teachers in guiding, monitoring, and evaluating AI-enhanced learning experiences.

## **Literature Review**

Schmid et al. (2021) emphasized that critical thinking is a central competency in STEM education and that AI applications can play an important role in strengthening this skill. AI-supported tools encourage students to engage in higher-order cognitive processes, including pattern recognition, evidence evaluation, data interpretation, and informed decision-making. For example, Chassignol et al. (2018) indicated that AI-powered data analytics platforms enable students to work with authentic datasets, thereby supporting inquiry-based learning, hypothesis development, and evidence-based investigation. Integrating AI into STEM curricula can consequently foster students' curiosity, creativity, and innovative thinking, while preparing them for future careers that require advanced analytical and problem-solving capabilities (Brynjolfsson & McAfee, 2017).

In addition, AI can promote greater inclusivity in STEM education by responding to learners' diverse abilities, learning styles, and educational needs. Chen et al. (2020) reported that personalized learning algorithms support differentiated instruction by adapting learning content, activities, and feedback to individual students. This approach can help ensure that learners receive appropriate levels of support and challenge. AI-powered natural language processing tools may also assist non-native English speakers in understanding complex scientific and technical terminology, thereby reducing language-related barriers and promoting more equitable learning opportunities in STEM fields (Woolf, 2019). Furthermore, Graham (2021) argued that AI-based

assistive technologies, including speech-recognition systems and adaptive assessment tools, can support students with disabilities and improve the accessibility and equity of STEM education.

Artificial Intelligence (AI) has become an increasingly important component of STEM education, with substantial implications for instructional practices and student learning outcomes. The integration of AI technologies has contributed to the development of more personalized learning experiences and has supported the enhancement of students' problem-solving and critical-thinking skills. Consequently, AI has the potential to reshape traditional learning environments by making instruction more adaptive, interactive, and responsive to students' individual needs. Recent educational research has extensively examined AI-based innovations, including intelligent tutoring systems, adaptive learning platforms, and virtual laboratories. These technologies have demonstrated potential for promoting student engagement, supporting deeper understanding, and improving learning experiences in STEM disciplines (Holmes et al., 2019). A major advantage of AI in STEM education is its capacity to provide individualized learning experiences that are tailored to each student's abilities, needs, and learning pace. Machine-learning algorithms can analyze students' performance data and use this information to generate customized instructional pathways and learning activities at appropriate levels of complexity (Luckin, 2017). AI-powered instructional systems further enhance this process by offering immediate feedback that enables students to identify and correct misconceptions while developing a stronger understanding of complex STEM concepts (Zawacki-Richter et al., 2019). Such personalized and responsive approaches can increase students' motivation, strengthen their engagement with learning activities, and make STEM subjects more accessible and meaningful for diverse learners (Chen et al., 2020).

Artificial Intelligence also plays a significant role in developing students' problem-solving skills by enabling them to engage with dynamic and interactive learning environments. AI-

powered virtual laboratories and simulations provide opportunities for students to conduct practical experiments, explore scientific phenomena, and analyze results in accessible and risk-free settings (Molnar, 2020; Popenici & Kerr, 2017). These environments encourage learners to formulate hypotheses, manipulate variables, test possible solutions, and interpret findings, thereby strengthening their ability to address problems systematically and apply scientific reasoning. In addition, AI-supported collaborative tools can enhance collective problem-solving by enabling students to work together on complex tasks and projects. Such tools may provide assistance with data analysis, visualization, feedback, and the organization of shared learning activities, allowing students to benefit from both peer interaction and AI-based support (Schmid et al., 2021; Dillenbourg, 2020). Through these collaborative and interactive experiences, AI can contribute to the development of students' analytical thinking, teamwork, and capacity to solve complex STEM-related problems.

Xu and Ouyang (2022) conducted a systematic review of 63 experimental studies published between 2011 and 2021 to examine the impact of Artificial Intelligence on STEM education. Their review identified six major categories of AI applications and highlighted the relationships between these applications and other instructional elements, including information resources, media, and learning environments. The findings also emphasized the pedagogical and technological implications of integrating AI into STEM education, particularly in relation to improving instructional design, supporting interactive learning experiences, and enhancing students' engagement with STEM content. Similarly, Li et al. (2024) reviewed 47 experimental studies that investigated the outcomes of AI-based educational programs in primary and secondary education. Their findings indicated that well-designed, practical AI-supported learning tasks can promote deeper understanding and encourage students' active participation in learning activities. The study

further suggested that AI-based educational programs can be particularly effective when they provide learners with meaningful opportunities to apply knowledge, explore concepts, and engage actively with instructional content.

As Artificial Intelligence continues to advance, its role in shaping the future of STEM education is becoming increasingly significant. AI-driven innovations can enable educators to create more engaging, interactive, and adaptive learning experiences that support the development of students' problem-solving and critical-thinking skills (Estevez et al., 2020). By integrating AI tools thoughtfully into STEM instruction, teachers can provide learners with opportunities to explore complex concepts, receive timely feedback, and engage in meaningful learning activities that reflect real-world challenges. Future research should therefore focus on improving the effective application of AI in STEM education, examining the ethical implications associated with its use, and identifying appropriate strategies for integrating AI across diverse educational contexts. Attention should also be given to issues related to data privacy, algorithmic bias, equitable access, and teacher preparedness. Through a balanced, responsible, and ethically informed approach, AI has the potential to transform STEM education and equip students with the knowledge, skills, and competencies needed to succeed in an increasingly AI-driven world.

The rapid advancement of Artificial Intelligence (AI) applications has encouraged the Saudi Arabian education system to develop smart electronic systems that support collaborative learning within the educational community (Mutambik, 2024). These initiatives seek to enhance the adoption and effective use of AI applications across Saudi educational settings (Al-Hamoud, 2021). Grah (2020) noted that AI-supported communication and learning environments in Saudi education can provide alternatives to conventional digital technologies by relying on more advanced, interactive, and engaging technological solutions.

At the same time, STEM education in Saudi Arabia has experienced considerable development in alignment with the objectives of Saudi Vision 2030. Initial attention to STEM education emerged through research and planning efforts around 2017, followed by practical implementation through the establishment and preparation of specialized centers in educational regions. These centers aim to strengthen students' scientific thinking, creativity, innovation, and problem-solving abilities. Such efforts have contributed to broader national initiatives, including STEAM 2025–2030, which seek to prepare an innovative generation capable of contributing to a knowledge-based and technologically advanced society. Within this context, the current study investigates the role of integrating Artificial Intelligence technologies into STEM education in enhancing students' problem-solving and critical-thinking skills.

### **Research Questions**

1. What are the perceptions of science secondary school teachers towards integrating of AI in STEM education with respect to enhancing students' problem-solving and critical thinking skills?
2. Is there a significant difference between male and female perceptions?

### **Methodology**

This study will employ the mixed research approach. It is suitable for providing teachers with the opportunity to self-assess their level of possession of experiences regarding both artificial intelligence and STEM education, and their role on enhancing problem-solving and critical thinking skills.

### ***Population and Sampling***

The population of this study is the science teachers in the Asir region. Total of 180 science teachers were randomly selected as the study sample. Of this sample, 88 were males and 92 were females.

### ***Instrumentation and producers***

Two instruments were used in this study. The first instrument is a questionnaire. The questionnaire items were developed by the authors considering the previous literature in the field. The questionnaire consists of 33 items divided into four sections. The first section, "STEM Education Approach," comprises eight items and measured perspectives on the advantages of the STEM approach in education. The second section, "Artificial Intelligence," consists of seven items measuring opinions on artificial intelligence and its impact on education. The third section, "Problem-Solving Skills," comprise nine items measuring perspectives on enhancing problem-solving skills through the integration of artificial intelligence in STEM education. The fourth section, Critical Thinking Skills, consists of nine items measuring perspectives on enhancing critical thinking skills through the integration of artificial intelligence in STEM education. Participants used a five-point scale: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5). The scores for each item were totaled to provide individual scores for each component, and the negative items were reverse-coded to allow for meaningful subscale analyses.

Content validity was established to determine the questionnaire's validity, based on the opinions of seven university professors with expertise in using artificial intelligence in education. These professors hold doctoral degrees in either e-learning or science education and are familiar with AI applications in education. The split-half method was used to determine the questionnaire's reliability. A coefficient of 0.83 was considered a highly acceptable indicator of the questionnaire's reliability. The questionnaires were distributed to participants in the 2025/2026 academic year, at the beginning of the second semester. All participants completed the questionnaires during the second week of the semester.

The second instrument that was used is the interview. It provides the opportunity to support teachers' opinions and clarify them. The conducted interview is semi-structured whereby the questions draft is provided as guidelines and are conducted individually. The interview took between 30 – 45 minutes. Total of 12 science teachers who have responded to the questionnaire were interviewed. The interview comprises 5 open-ended questions developed by the authors. These questions mainly focused on issues such as the nature of the STEM approach, the importance of artificial intelligence in education, and methods for developing problem-solving and critical thinking skills. The content validity of the interview questions was calculated by presenting them to four experienced and specialized referees to give their comments in terms of determining the degree of suitability of the interview questions, their comprehensiveness, the degree of clarity of the questions, and their linguistic and grammatical correctness, and stating the proposed modifications, then adopting the 80% agreement rate, and then agreeing on their suitability to achieve the goals for which they were set. A coefficient of 0.83 was considered a highly acceptable indicator of the questionnaire's reliability.

The questionnaires were distributed to participants in the 2025/2026 academic year, at the beginning of the second semester. All participants completed the questionnaires during the second week of the semester. The interview was conducted by selecting 6 male teachers and 6 female teachers who completed the questionnaire. The interviews were recorded and the data was then written down for later analysis.

## **Results**

Science teachers' perceptions of integrating artificial intelligence (AI) into STEM education were measured through assessing the enhancement of both AI and STEM education to problem-solving and critical thinking skills. Table 1 shows the mean scores of participants and their standard deviations for the four dimensions. Participants scored highest in AI (mean = 4.45), indicating that

AI is the most important element of integration. This was followed by the STEM education component (mean = 4.27). Critical thinking skills (mean = 4.08) were highly valued, while problem-solving skills received the lowest scores (mean = 3.92). This suggests that critical thinking skills are enhanced more by the integration process than problem-solving skills. Overall, all these high average values indicate that science teachers were more positive about using AI in STEM education to enhance the learning of both critical thinking and problem-solving skills.

Table 1 Descriptive statistics and reliability coefficient for each subscale (n=180)

| Factors                  | Mean | SD   | alpha |
|--------------------------|------|------|-------|
| STEM Education Approach  | 4.27 | 0.42 | 0.87  |
| Artificial Intelligence  | 4.45 | 0.77 | 0.79  |
| Problem-Solving Skills   | 3.92 | 0.91 | 0.82  |
| Critical Thinking Skills | 4.08 | 0.62 | 0.84  |
| Overall perception items | 4.18 | 0.70 | 0.83  |

At the overall level, the science teachers' perception is very well (4.18), and this indicates that science teachers held a positive thought regarding integrating AI in STEM education. The reliability coefficient for each subscale ranges from high (0.87) to moderate (.79). The reliability for the whole scale is high (0.83).

The relationship among the four factors within the integration process (STEM education approach, AI, problem solving skill, and critical thinking skills) is shown in table 2. All the components are closely related at the statistical significance level  $p < 0.01$ , and the correlation coefficients range between 0.34 and 0.57. This indicates a good relationship between the components of the factors as dependent and independent variables, and this is related to the constancy of science teachers' perceptions towards the integration of artificial intelligence in STEM education and its impact on problem-solving and critical thinking skills.

Table 2 The correlation matrix of the integration factors

| Factors                        | Artificial Intelligence | SEA  | PSS  |
|--------------------------------|-------------------------|------|------|
| STEM Education Approach (SEA)  | 0.34                    |      |      |
| Problem-Solving Skills (PSS)   | 0.57                    | 0.40 |      |
| Critical Thinking Skills (CTS) | 0.55                    | 0.35 | 0.54 |
| * $p < .01$ (2-tailed)         |                         |      |      |

As revealed in table 3, no significant difference was found among science teachers regarding the gender ( $t = 0.02$ ,  $P < 0.05$ ). So, these scores suggest that male and female science teachers share the same perceptions toward the integration of AI within STEM education.

Table 3 The difference between science teachers' perceptions regarding the gender

| Gender | n  | Mean | SD   | t-value | $p$     |
|--------|----|------|------|---------|---------|
| Male   | 88 | 3.90 | 0.94 | 0.02    | $>0.05$ |
| Female | 92 | 3.87 | 0.98 |         |         |

The qualitative findings of this study revealed that the STEM approach is familiar to most of the interviewed teachers, with over 9 out of 12 teachers indicating their use of the STEM approach in teaching some science topics. Teachers have evaluated STEM teaching as an effective strategy for studying natural phenomena in light of integration with AI. At the same time, the responses from those interviewed teachers reflected that integrating artificial intelligence applications into STEM education clearly and strongly enhances this type of education and enables students to learn in better conditions, as it facilitates interaction and participation during the learning process. On the other hand, they emphasized the importance of learning science issues by presenting them as problems and challenges that lead to the development of problem-solving and

critical thinking skills. They also indicated that integrating artificial intelligence applications into STEM education leads to the enhancement of these skills.

## **Discussion**

As indicated from the results, science teachers showed positive perceptions towards the integrating AI within STEM education, as shown by the mean score for each factor which ranged between 3.92 and 4.45. The overall level of positive perceptions of science teachers toward integration could be interpreted in term of the potential encouragement of the educational sector in Saudi Arabia to use both AI and STEM education. At the same time, facilities offered by schools to using technologies could be the other reason that enable science teachers to employ AI in their teaching. This finding is supported by the study of Mutambik (2024) which suggested a positive relationship between AI and STEM education.

Similarly, the increased use of computers in Saudi schools could have promoted greater opportunities of using related technologies, especially the Internet. It is expected that science teachers will benefit from the technologies offered by the ministry of Education in Saudi Arabia. Furthermore, the openness of Saudi education to international educational practices and the adoption of new approaches to address the challenge enable science teachers in the Kingdom to develop their skills and understanding of the nature of education in the current era. This was confirmed by Al-Hamoud, 2021) as stated previously on the literature.

## **Conclusion**

Providing Saudi science teachers with the opportunity to engage with modern technology, particularly artificial intelligence, has enabled them to acquire digital literacy and subsequently integrate it into their teaching. This is demonstrated by the results of this study, which show that science teachers have demonstrated a remarkable awareness of the importance of modern

technologies and their application in education. Therefore, this study recommends further curriculum adjustments in light of artificial intelligence applications to ensure high-quality and valuable learning outcomes. The study also suggests further research into the impact of integrating artificial intelligence into STEM education on the development of other student skills, such as personalized learning, scientific writing, and creative thinking.

## **Declarations**

**Ethics approval :** This study was exempt from formal Institutional Review Board (IRB) approval in accordance with the regulations of King Khalid University, Saudi Arabia. The research relied entirely on anonymous, voluntary surveys and semi-structured interviews completed by adult participants, involving no medical interventions or collection of biological samples. Under institutional guidelines, this type of survey- and interview-based educational research qualifies for an exemption.

**Consent to participate:** Informed consent was obtained from all participants (N = 192) before their participation in the study, including 180 participants who completed the online questionnaire and 12 participants who took part in the semi-structured interviews. Participation was entirely voluntary. Before participating, all participants were informed about the purpose and procedures of the study, the voluntary nature of their participation, the confidentiality and anonymity of their responses, and their right to withdraw from the study at any time before completing their participation without any consequences. All collected data were used solely for academic and scientific research purposes.

**.Consent to publish:** Not applicable.

**Data Availability:** The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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**Competing Interests:** The authors declare that they have no competing interests.

**Authors' contributions :** All authors contributed equally to this study, They jointly contributed to the conceptualization and design of the research, development of the theoretical framework, data collection, data analysis, interpretation of the findings, manuscript drafting, critical revision, and approval of the final version of the manuscript for publication.

### **Supplementary Information**

#### Appendix 1: Research Instruments

This supplementary file contains the complete research instruments used in this study, including the Survey Questionnaire and the Semi-structured Interview Protocol.

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