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Maximizing the impact of artificial intelligence and generative AI on STEAM education: A comprehensive review

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Abstract

This paper extends the discussion on the significance of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education by examining the rapidly emerging roles of Artificial Intelligence (AI) and Generative AI (GAI) in fostering critical thinking, problem-solving, and creativity. By integrating these advanced technologies into STEAM curricula, educators can provide more personalized, interdisciplinary, and engaging learning experiences that cater to varied student needs. Throughout the paper, AI and GAI platforms are categorized into subgroups namely Adaptive Learning & Personalized Education, Programming & Data Analysis, Generative & Creative AI, Interactive & Immersive Learning, and Visual Design & Communication to illustrate diverse integration pathways. Ethical considerations, pedagogical strategies, and continuous teacher development are presented as key to responsible adoption. This review study includes the analysis of various peer-reviewed studies selected based on specific inclusion and exclusion criteria. Findings underscore the transformative potential of AI and GAI not only in enhancing student engagement and conceptual mastery, but also in promoting collaborative innovation across all STEAM disciplines. The study concludes with actionable recommendations for educators, policymakers, and researchers to embed AI and GAI tools effectively while ensuring equitable access, maintaining ethical standards, and emphasizing long-term professional growth.

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1. INTRODUCTION

Education plays a pivotal role in equipping individuals with critical thinking, problem-solving, and creativity skills vital for personal and societal development. In this context, STEAM (Science, Technology, Engineering, Arts, and Mathematics) education transcends traditional subject boundaries by promoting an interdisciplinary mindset (Tsupros et al., 2009). Scholars have pointed out that STEAM education not only delivers academic content but also nurtures the competencies required in our rapidly evolving world, encouraging students to generate creative solutions to complex problems (Tüzün & Tüysüz, 2018; Erol, 2023).

As rapid advancements in AI continue to shape multiple sectors, education has increasingly embraced these technologies to enhance student engagement and tailor learning experiences (Russell & Norvig, 2021; Ece, 2024). Among the noteworthy AI subfields is Generative AI (GAI), which has the capacity to create new content such as text, images, and music by analyzing patterns within given datasets (Liu, 2023; Vafadar & Amani, 2024). This study aims to examine the role of Artificial Intelligence (AI) and Generative AI (GAI) in STEAM education, exploring how these technologies support students' critical thinking, problem-solving, and creativity skills. Serving as a guide for educators, policymakers, and researchers, this study systematically categorizes AI and GAI tools to provide a structured framework for their effective integration into STEAM curricula. Furthermore, it addresses key considerations such as ethical concerns, teacher training, and student-centered approaches, offering recommendations for the sustainable and effective implementation of AI-enhanced STEAM education.

1.2. The Importance of STEAM Education

STEAM education supports students' acquisition of 21st-century skills, which include creativity, critical thinking, problem-solving, collaboration, ethical behavior, aesthetic awareness, initiative-taking, communication, data literacy, curiosity, self-management, and holistic thinking (Bölükbaş, 2024). By integrating Art into STEM subjects, STEAM fosters a learning environment that capitalizes on students' natural inclination toward creative exploration (Johnston & Kervin, 2022; DeJarnette, 2018). Consequently, STEAM curricula effectively boost student motivation and deepen learning through hands-on experiences that make real-world connections (Wahyuningsih et al., 2020a; Cook et al., 2020).

Numerous studies also underscore the importance of STEAM approaches in early childhood education, given young learners' innate curiosity and willingness to experiment (DeJarnette, 2018; Wahyuningsih et al., 2020b). Activities that leverage flexible materials or thematic play not only enhance cognitive development but also promote social-emotional growth (Garner et al., 2017; Budiyanto et al., 2021). Overall, STEAM education holistically fosters a range of competencies, preparing learners to meet the demands of the 21st-century workforce and society (Johnston & Kervin, 2022; Wahyuningsih et al., 2020).

1.3. Artificial Intelligence and Generative AI: Key Concepts

Artificial Intelligence (AI) refers to computer systems designed to replicate human-like cognitive functions, including learning, problem-solving, and decision-making (Russell & Norvig, 2021). Originating from the pioneering work of Alan Turing in the 1950s (Carricho, 2018), AI has undergone rapid evolution in recent years, driven by innovations in machine learning and deep learning. These advancements have enabled computers to process vast amounts of data and autonomously adapt decision-making processes (Ece, 2024). AI literacy an emerging concept advocates for an informed understanding of AI's capabilities and limitations, ensuring its ethical and responsible application (Elçiçek, 2024).

Generative AI (GAI) is a distinct subfield of AI that specializes in producing new content such as text, images, or music derived from existing datasets (Liu, 2023; Vafadar & Amani, 2024). Unlike conventional AI, which often focuses on solving specific tasks through data-driven insights, GAI emphasizes creative outputs (Ma, 2022). While AI typically targets analytical problem-solving and optimization, GAI delivers innovative solutions and original creations (Bryndin, 2019). This attribute renders GAI particularly valuable in creative domains such as arts, design, and education, where the generation of novel ideas or artifacts is paramount.

1.4. The Role of AI and Generative AI Tools in STEAM Education

AI and GAI tools increasingly occupy a central position in STEAM education by enhancing students' creative and analytical skill sets. These technologies can transform traditional learning environments by allowing deeper exploration of complex concepts, personalized learning trajectories, and data-driven feedback (Chen et al., 2020). AI-powered systems can analyze student performance in real time, adapt content, and present customized problem sets to optimize individual learning outcomes (Chen et al., 2020; Niu et al., 2022). Generative AI, on the other hand, enriches STEAM projects by supporting the creation of digital art, music compositions, and simulations. Students can develop both creative abilities and technical prowess, bridging disciplines such as engineering and design (Koul et al., 2022). Engaging with AI and GAI tools also cultivates students' algorithmic thinking skills, reinforcing the STEAM philosophy of integrated problem-solving. Consequently, these platforms help educators scaffold intricate concepts and foster learning experiences that resonate with a diverse set of learners (Kim & Kim, 2022).

Crucially, AI and GAI tools promote personalized, student-centered learning while enabling teachers to provide individualized guidance (Relmasira, 2023). Educators can leverage these platforms to develop or refine pedagogical strategies that cater to different learning styles, resulting in more efficient and meaningful educational outcomes (Cook et al., 2020; Hapidin et al., 2020). Despite their transformative potential, the adoption of AI and GAI comes with responsibilities, including data privacy, algorithmic fairness, and the need for robust teacher training (Klímová et al., 2023; Ayanwale, 2024).

1.5. Pedagogical Approaches and Professional Development

AI integration in STEAM education calls for educators who possess both subject-matter expertise and AI literacy (Elçiçek, 2024). Continuous professional development (CPD) programs are essential to support teachers in confidently using AI-based educational tools and guiding students in a technology-driven learning environment. Studies have shown that these tools significantly improve student engagement and learning outcomes, yet their effectiveness depends greatly on teachers' capacity to integrate AI solutions effectively into curricula (Niu et al., 2022; Chen, Huang & Chen, 2020).

Trust also plays a crucial role: educators must trust AI systems to be fair, reliable, and beneficial to student development (Ayanwale, 2024). By emphasizing the pedagogical benefits and offering hands-on training, educators can establish a constructive relationship with AI technologies. Additionally, the ethical implications of AI, such as bias and privacy concerns, should be addressed through well-structured guidelines and transparent data practices (Klímová et al., 2023).

1.6. AI Tools for STEAM Education

In Table 1, various AI tools and their functions, along with example scenarios in STEAM education, are presented. Table 1 clearly illustrates the various AI tools used in STEAM education and how these tools can be integrated into educational processes. Each tool enhances the learning experience by providing personalized learning, robust analytical support, or adaptive tutoring, thereby making the learning process more effective and efficient. These tools enable educators to create lesson content tailored to the needs of students and allow for progression based on individual learning paces. The potential of AI technologies in the STEAM field presents significant opportunities for advancing innovation in education.

Tablo 1. *AI Tools in STEAM Education*

AI Tool	Function	Example Scenario in STEAM Education	Access Link
IBM Watson Education	AI-powered personalized learning	A middle school science teacher uses IBM Watson to analyze student assessments, providing personalized feedback to support struggling learners.	IBM Watson Education
Google AI for Education	AI tools for natural language processing & analytics	A history teacher integrates Google AI's natural language processing tools to help students analyze historical texts and generate summaries.	Google AI for Education
CogniTutor	AI-based adaptive tutoring	A math teacher assigns CogniTutor to students struggling with algebra. The platform identifies weak areas and provides customized exercises.	CogniTutor
Querium	AI-enhanced STEM learning	A physics teacher uses Querium's AI-driven tutoring system to help students master kinematics through step-by-step problem-solving guidance.	Querium
Century Tech	AI-driven personalized education pathways	A high school computer science class uses Century Tech to track student progress in Python programming and adjust learning materials accordingly.	Century Tech
Squirrel AI Learning	Adaptive AI learning	In a flipped classroom setting, Squirrel AI assigns customized pre-class learning modules based on individual student performance.	Squirrel AI Learning
Python	Programming for AI & machine learning	Students in a computer science course use Python and TensorFlow to build a simple AI model that classifies handwritten digits.	Python
Jupyter Notebook	Interactive coding & data visualization	A statistics class uses Jupyter Notebook to analyze climate change data and visualize trends using Python libraries.	Jupyter Notebook
TensorFlow	Machine learning framework	An engineering class builds a neural network in TensorFlow to classify images of different bridge structures for structural analysis.	TensorFlow
PyTorch	Deep learning framework	A university AI lab utilizes PyTorch for a student-led project on self-driving car simulations, training AI models on real-world datasets.	PyTorch
R Programming	Statistical computing & AI modeling	A data science course applies R to analyze student performance trends and predict success in STEAM subjects.	R Programming

2. Generative AI Tools for STEAM Education

The following table presents various generative AI tools for STEAM education, along with their functions, example scenarios in STEAM education, and access links.

Tablo 2. *Generative AI Tools in STEAM Education*

Generative AI Tool	Function	Example Scenario in STEAM Education	Access Link
Code.org	Enhances computer science and coding skills through interactive lessons and games.	A middle school teacher uses Code.org's interactive lessons to teach students foundational coding concepts and logic.	Code.org
ChatGPT (OpenAI)	Assists with writing, problem-solving, and coding tasks; transforms learning processes in diverse settings.	Students use ChatGPT to brainstorm ideas, solve coding challenges, and receive real-time feedback during their computer science class.	ChatGPT
Bing Chat (Microsoft)	An AI-assisted chat platform offering STEM-related information and interactive learning.	A high school physics teacher uses Bing Chat to facilitate interactive discussions on complex topics like quantum mechanics and relativity.	Bing Chat
Google AI Tools (e.g., Quick Draw, Auto Draw)	Facilitates AI-driven content creation in arts education, inspiring student creativity.	In an art class, students use Google's Quick Draw to explore AI-based drawing prompts, enhancing their creativity and artistic skills.	Google AI Tools
Augmented Reality (AR) and Virtual Reality (VR) Tools (e.g., Google Expeditions)	Immersive tools that help students comprehend complex concepts through interactive learning experiences.	Students use Google Expeditions in a history class to virtually explore ancient civilizations, deepening their understanding through immersive experiences.	Google Expeditions
AI-Powered Educational Platforms (e.g., Khan Academy, Coursera)	Adjust content to student performance for a personalized, adaptive learning experience.	A biology student uses Khan Academy to progress through personalized lessons on genetics and cell biology, adjusting content based on their learning pace.	Khan Academy
AI Chatbots	Provide immediate feedback and resources, thereby increasing interactivity in learning.	Students use AI chatbots to get quick answers to questions while working on STEM projects, improving engagement and learning efficiency.	AI Chatbots
Learning Analytics Dashboards	Optimize teaching strategies by analyzing student data and identifying growth areas.	A teacher uses learning analytics dashboards to track student progress in chemistry and adapt teaching strategies accordingly.	Learning Dashboards
Canva	Encourages the development of communication and design skills by enabling user-friendly graphic creation.	In a design class, students use Canva to create infographics about climate change, combining art and science to visualize data.	Canva
DALL•E (OpenAI)	Generates original visual content, empowering students to explore creativity in art and design projects.	Students use DALL•E to generate unique illustrations for a storytelling project, enhancing their visual design and narrative skills.	DALL•E
DeepArt.io	Transforms existing images into artistic renditions, helping students learn about different art styles.	In an art history class, students use DeepArt.io to transform photographs into famous art styles, exploring visual storytelling techniques.	DeepArt.io

Runway ML	Allows the development of digital art, animations, and graphic designs via deep learning models.	Students in a media arts class use Runway ML to create short animations that explain the principles of physics, such as motion and energy.	Runway ML
Soundraw	Enables the AI-driven composition of music, fostering creativity and self-expression.	A music class uses Soundraw to compose original soundtracks for a film project, learning about music production and digital composition.	Soundraw
Miro AI	Supports brainstorming, ideation, and collaborative content creation in group projects.	In a group project, students use Miro AI to collaborate on designing a robotic prototype, utilizing brainstorming tools and AI suggestions.	Miro AI
GPT-3 API (OpenAI)	Allows students to develop custom AI applications such as chatbots and text-generation platforms.	Students use GPT-3 to create a chatbot for a language learning project, enhancing their programming skills and understanding of AI concepts.	GPT-3 API
StableDiffusion	An open-source GAI model for generating original images, applicable in various art projects.	In an art class, students use StableDiffusion to generate illustrations based on prompts that reflect their creative interpretation of a theme.	StableDiffusion
Artbreeder	Merges multiple visuals to create unique artwork, useful for exploring concepts of genetics and artistic variation.	Students in a biology class use Artbreeder to create visual representations of genetic traits and inheritance patterns.	Artbreeder
Craiyon (formerly DALL•E Mini)	Generates images from textual prompts, providing a user-friendly tool for design exercises.	A graphic design student uses Craiyon to create concepts for a new product design, experimenting with different visual styles.	Craiyon
Magenta (Google)	Facilitates the creation of music and art through AI, enabling students to experiment with digital media.	Students use Magenta to compose music and generate visual art, exploring how AI can intersect with creativity in a multimedia project.	Magenta
DeepDream (Google)	Uses image recognition algorithms to produce abstract and fantastical transformations of standard photos.	In an art class, students use DeepDream to create surreal images from photographs, learning about algorithms and creative expression.	DeepDream
JukeBox (OpenAI)	Analyzes music patterns and generates new songs, helping students understand and explore musical structures.	Music students use JukeBox to analyze musical trends and compose new pieces in various genres, learning about music theory and composition.	JukeBox
Scribbl (Google)	Enhances simple sketches with AI-generated artistic details, acting as a source of inspiration in art classes.	Art students use Scribbl to refine their sketches by adding AI-generated details, improving their understanding of design and creativity.	Scribbl
ThisPersonDoesNotExist	Generates fictional human faces, beneficial for character design and digital storytelling projects.	Students use ThisPersonDoesNotExist to create fictional characters for a digital storytelling project, learning about character design principles.	ThisPersonDoesNotExist

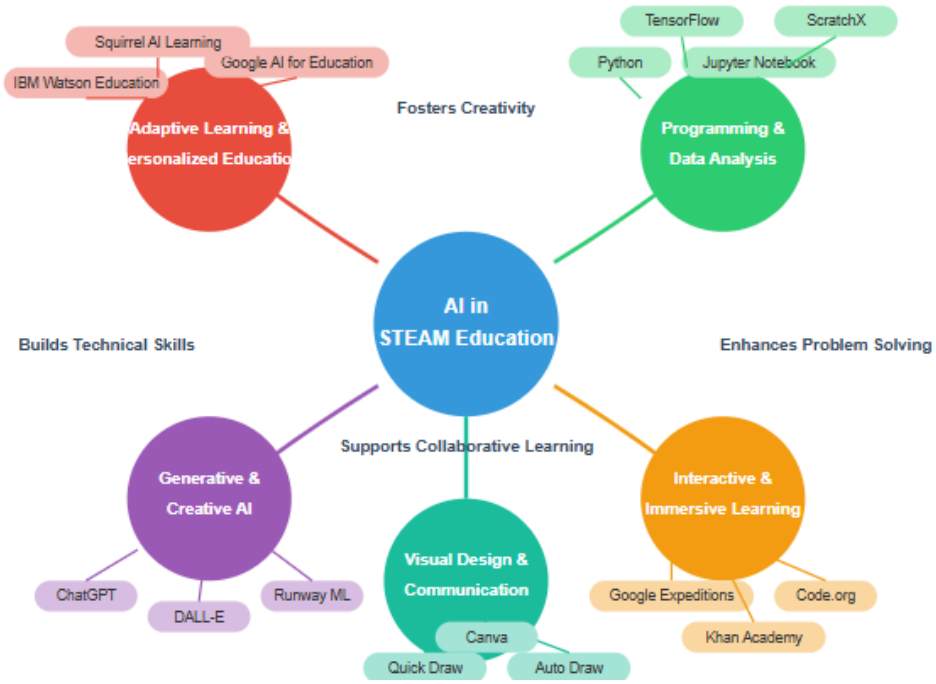
Pikazo	Reimagines photographs in the style of famous painters, facilitating the study of art history and design.	Art history students use Pikazo to explore and recreate famous paintings, learning about different artistic styles and techniques.	Pikazo
AIVA (Artificial Intelligence Virtual Artist)	Composes original music in various styles, allowing students to experiment in music composition.	In a music class, students use AIVA to compose music for a multimedia project, experimenting with various styles and genres.	AIVA
PictoBlox	A block-based coding environment tailored to AI and robotics, ideal for beginners.	Students in a robotics class use PictoBlox to program robots for AI-based tasks, learning basic coding and robotics concepts.	PictoBlox
mBlock	Integrates Scratch-based coding with AI and machine learning, streamlining the creation of entry-level AI projects.	Students use mBlock to create simple AI projects, such as a chatbot or automated system, helping them grasp basic machine learning concepts.	mBlock
ScratchX AI Extensions	Extends the Scratch platform to incorporate AI functionalities, simplifying basic AI concept exploration.	A coding class uses ScratchX to build interactive projects, exploring the integration of AI features like speech recognition and computer vision.	ScratchX
Codey Rocky (Makeblock)	Combines robotics and AI, giving students hands-on experience in programming physical hardware for AI tasks.	Students use Codey Rocky to create and program robots for AI tasks, applying their knowledge of both coding and robotics in practical scenarios.	Codey Rocky
Teachable Machine (Google)	Allows users to collect data and train AI models using intuitive, block-based programming.	Students use Teachable Machine to train AI models to recognize images or sounds, learning the fundamentals of AI and machine learning.	Teachable Machine

Table 2 illustrates how generative AI tools used in STEAM education can be integrated into teaching processes and their role in education. These tools enable students to develop creative thinking and problem-solving skills in areas such as coding, art, music, robotics, and artificial intelligence, while also offering teachers the opportunity to provide customized content based on individual learning speeds. AI-powered tools facilitate the application of theoretical knowledge, allowing students to creatively use technology and promoting deep, interdisciplinary learning experiences.

2.1. Innovative Groupings of AI Tools for STEAM Education

Modern STEAM curricula increasingly require educators to employ a variety of AI tools tailored to different learning objectives. By systematically grouping these tools based on their unique functionalities, educators can more effectively pinpoint the resources that best suit their lesson goals. From adaptive learning systems to creative generative AI, each category plays a vital role in enriching student engagement and understanding. The paragraphs below explore each grouping in more detail, explaining how these specialized tools can elevate STEAM education. In the concept map, the AI tools have been systematically categorized to reflect their primary functions and how they can be applied within STEAM education. Rather than listing the tools randomly, the grouping is based on the specific features each platform or library offers ranging from adaptive learning systems and programming frameworks to generative creativity tools. The goal is to make it easier for educators and researchers to identify which tools best align with the learning outcomes they aim to achieve in various STEAM activities.

Figure 1. *A concept map of AI and STEAM Education correlations with five categories.*



Adaptive Learning & Personalized Education tools (e.g., IBM Watson Education, Google AI for Education, and Squirrel AI Learning) adapt content to a student's current level of understanding. In STEAM contexts, this is particularly important because learners often have varying degrees of skill in mathematics, coding, and project-based engineering tasks. Tools that personalize learning ensure that students move at a suitable pace, receiving additional support or accelerated challenges as needed. This model not only keeps students engaged but also frees up instructors to focus on activities that foster creativity and higher-order problem-solving.

Shifting to **Programming & Data Analysis**, platforms like Python, Jupyter Notebook, and TensorFlow form the backbone of computational thinking in STEAM education. They enable students to write code that models scientific phenomena, automates engineering processes, and even generates data-driven visual art. For younger or less experienced learners, block-based environments such as mBlock and ScratchX AI Extensions—lower the entry barrier. Instead of grappling with syntax, students can experiment with fundamental AI and robotics concepts, which fosters confidence and prepares them for more advanced coding challenges.

Meanwhile, **Generative & Creative AI** services (ChatGPT, DALL-E, Runway ML, and others) serve as catalysts for innovative projects that merge art with technology. Learners can craft AI-generated music, create one-of-a-kind visuals for geometry lessons, or even build story scenarios that illustrate scientific principles. By prompting students to work in this hybrid zone of digital creativity, educators invite them to cultivate not just technical expertise but also an appreciation for aesthetics, design thinking, and imaginative storytelling key ingredients of the "A" in STEAM.

For immersive experiences, **Interactive & Immersive Learning** tools like Google Expeditions, Code.org, and Khan Academy offer virtual and augmented reality modules, coding exercises, and self-paced educational tracks. These tools help students visualize abstract concepts such as molecular structures or physics simulations and encourage active learning through gamified challenges. By embedding real-time feedback and progress tracking, they sustain learners' motivation and allow teachers to pinpoint areas where further intervention or extension activities may be needed.

Finally, **Visual Design & Communication** solutions (Quick Draw, Auto Draw, Canva) highlight the importance of aesthetic presentation and clear communication in STEAM. Whether students are showcasing experiment data, designing engineering prototypes, or curating an art-and-technology gallery, these tools enable them to articulate their findings compellingly. As modern workplaces value both technical

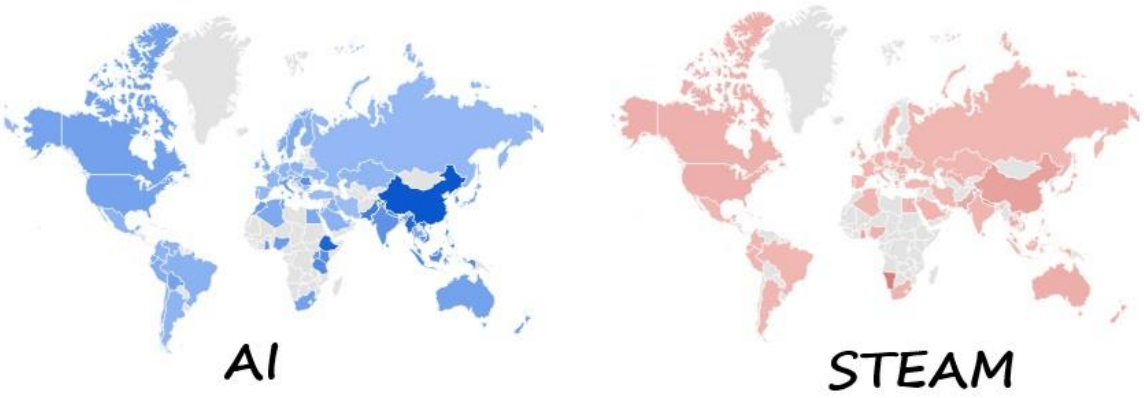
competencies and effective storytelling, mastering visual communication ensures that students' ideas resonate with broader audiences, be it in professional conferences or school-wide exhibitions.

Overall, categorizing AI tools in this way provides a holistic roadmap for educators to integrate technology seamlessly into the STEAM environment. Each subcategory caters to a unique facet of learning—from adaptive support to creative expression ensuring that students develop a broad spectrum of skills. By exploring these tools strategically, teachers can craft lessons that highlight the connections between scientific inquiry, technological innovation, engineering problem-solving, artistic creativity, and mathematical reasoning, preparing learners for the multifaceted challenges of the 21st century.

2.2. Bridging AI and STEAM Education: Emerging Trends and Synergies

Recent data from Google Scholar indicates that there are about 7.99 million articles featuring "AI" in their titles, compared to 2.72 million documents focusing on "STEAM education." Despite the apparent discrepancy in sheer volume, both concepts demonstrate robust academic interest and continue to gain traction in educational research. AI has long been hailed as a transformative technology across industries, while STEAM education emphasizes an interdisciplinary approach integrating science, technology, engineering, arts, and mathematics to foster critical thinking and creativity. These parallel evolutions point toward a growing recognition that modern education must address the demands of a world shaped by rapid technological advancement. Furthermore, a Google Trends analysis comparing searches for "AI" and "STEAM education" reveals an 87% correlation, suggesting that as public interest in one concept rises, the other tends to follow a similar trajectory (Figure 1). This relationship underscores the increasingly intertwined nature of technological innovation and holistic educational frameworks. Scholars and practitioners alike appear to be seeking ways to merge AI's computational power with STEAM's hands-on, project-based learning strategies. In doing so, they aim to equip learners not only with technical expertise but also with creative problem-solving skills that transcend disciplinary boundaries.

Figure 2. *Search comparisons of the concepts of AI and STEAM education*



The strong correlation and mounting academic references signal a critical juncture: as AI continues to evolve at breakneck speed, STEAM education must adapt to integrate AI-driven tools and methodologies. Incorporating AI in STEAM curricula can spark greater student engagement, hone analytical thinking, and nurture artistry collectively preparing learners for 21st-century challenges. By uniting these two arenas, educators and policymakers can foster a generation of innovators capable of leveraging AI's potential in ethically responsible and creatively inspired ways.

3. CONCLUSION

AI and Generative AI (GAI) are revolutionizing STEAM (Science, Technology, Engineering, Arts, and Mathematics) education by making learning experiences more interactive, personalized, and creative. Recent Google Trends data, for instance, reveals a significant correlation—over 80%—between searches for "AI" and "STEAM education," underscoring a growing, interconnected public interest in both topics. As AI tools continue to evolve, they offer a powerful means to tackle complex STEAM concepts, encouraging students to forge interdisciplinary connections and develop problem-solving skills vital for the 21st-century workforce (Johnston & Kervin, 2022; DeJarnette, 2018; Wahyuningsih et al., 2020). These tools not only present information to students but also challenge them to think critically and creatively, applying their knowledge to real-world problems. For example, students can use AI-powered software to develop solutions to engineering problems and then relate these solutions to practical applications in the real world. These experiences allow students to enhance both their theoretical knowledge and practical skills (Chen & Gutmann, 2019; ,Marar, 2024).

Nevertheless, the incorporation of AI into STEAM curricula requires strategic planning and close attention to ethical considerations such as fairness, privacy, and inclusivity (Klímová et al., 2023). It is essential that educators receive training not only on how to use AI tools but also on how to identify and mitigate biases that may exist in algorithmic processes. Ethical training should also guide educators in making sure that resources are distributed equitably so that all students can benefit from these innovations (Yazıcı & Erkoç, 2023; Sincar, 2023). Beyond the technological affordances of AI and GAI, educators must also address issues of bias in algorithmic processes, data protection, and equitable resource distribution to ensure that all learners can benefit from these innovations. By aligning professional development with these concerns, teachers can learn to recognize, mitigate, and responsibly manage potential pitfalls while maximizing the pedagogical strengths of AI-driven platforms (Ayanwale, 2024). In this context, it is also crucial for educators to not only understand how to use AI tools but also how to consider the broader societal impact of these technologies. Teachers should receive more guidance on recognizing and addressing the ethical challenges of AI in the classroom (Pan, 2024).

Ongoing professional development for educators, transparent policy guidelines, and robust institutional support are essential for fully realizing the benefits of AI and GAI in STEAM education. Structured professional development programs that help teachers use AI tools securely and effectively will boost their confidence and skills. Creating platforms for teachers to share their experiences with AI can help spread best practices and facilitate collaboration (Semwaiko et al., 2024). Future research could delve into the long-term learning outcomes and motivational impacts of AI-based interventions, as well as explore strategies for fostering teacher capacity and confidence in effectively leveraging AI tools for different age groups. In particular, analyzing the long-term motivational effects of AI interventions will be critical in determining whether these technologies enhance students' engagement with learning. Expanding on existing studies, researchers might also investigate how AI-mediated approaches influence career trajectories and STEAM skill retention over time (Becker & Park, 2011). Additionally, larger-scale policy initiatives and cross-sector collaborations can further strengthen AI and GAI integration. Policymakers, industry partners, and educational institutions should work together to develop shared guidelines and standards, ensuring that these technologies are ethically applied. On a national level, there should be collaborative policies developed to strengthen AI education, which will shape not only the educators but also the way students interact with AI (Kim et al., 2022.) By prioritizing transparency in algorithmic decision-making and accessibility in resource allocation, stakeholders can better address the digital divide and extend AI-driven opportunities to underserved communities (Noble, 2018).

Ultimately, the synergy between AI/GAI and STEAM education signifies an evolving pedagogical landscape one in which creativity, technological fluency, and real-world problem-solving abilities converge. This synergy is not just about academic achievement but also about preparing students with lifelong skills such as critical thinking and creative problem solving. By working with AI tools, students can develop solutions to real-world problems, enhancing their practical and theoretical learning. As the correlation in public interest suggests, learners, educators, and societies at large are ready to embrace AI's transformative potential. By continuously refining these tools and pedagogical strategies, stakeholders can equip students with the critical, creative, and collaborative skill sets necessary to thrive in an increasingly interconnected global society

(Saavedra & Opfer, 2012). In this developmental process, it is important to collaborate with educators to ensure that AI tools are used effectively and that students are getting the most out of their learning experience.

4. RECOMMENDATIONS

Future research and educational policies should focus on areas such as the long-term effects of integrating AI and Generative AI (GAI) into STEAM education, teachers' confidence and competence in using AI tools, and ethical and equity considerations. Studies should investigate the long-term impacts of AI-based interventions on students' learning outcomes, motivation, and retention of STEAM skills, while also enhancing professional development programs to ensure that teachers are well-equipped to use these tools effectively. Educational policies must establish clear guidelines for the ethical use of AI tools in education, addressing issues such as algorithmic bias, data security, and equitable access to resources. Furthermore, robust infrastructure should be developed to ensure that all schools have access to these tools. Additionally, the role of AI education in preparing students for their careers should be explored, and policies should be formulated to develop skills aligned with workforce needs, ensuring that students are adequately prepared for future job markets.

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Declaration of Conflicting Interests and Ethics

The authors declare that there is no conflict of interest regarding this study. The research has been conducted in accordance with the principles of scientific research and publication ethics. The scientific and legal responsibility for the content published in IJEDAI lies with the authors. As this study is a literature review, it does not require approval from an ethics committee.

Authorship Contribution Statement

First Author: Contributed to the literature review and writing process.
Second Author: Contributed to the literature review and writing process.
Third Author: Took part in the final revision, writing process, editing, and approval of the manuscript.

REFERENCES

Aniskin, V., Korostelev, A., Львовна, Б., Kurochkin, A., & Sobakina, T. (2020). Teaching potential of integrated learning technologies smart, stem and steam. *Revista De La Universidad Del Zulia, 11(29),* 328-336. https://doi.org/10.46925//rdluz.29.21

Ayanwale, M. (2024). Exploring steam teachers' trust in ai-based educational technologies: a structural equation modelling approach. *Discover Education, 3(1).*https://doi.org/10.1007/s44217-024-00092-z

Belda-Medina, J. (2024). Ai-driven digital storytelling: a strategy for creating english as a foreign language (efl) materials. *International Journal of Linguistics Studies, 4(1),* 40-49. https://doi.org/10.32996/ijls.2024.4.1.4

Bölükbaş, E. (2024). *STEAM alan öğretmenlerinin robotik ve kodlama eğitimi için tasarlanan ters yüz öğrenme ortamına ilişkin görüşleri ve akademik başarıları* [Yüksek Lisans Tezi]. Bursa Uludağ Üniversitesi.

Bryndin, E. (2019). Practical development of creative life-saving artificial intelligence. *Communications, 7(2),* 31. https://doi.org/10.11648/j.com.20190702.11

Budiyanto, C., Shahbodin, F., Umam, M., Isnaini, R., Rahmawati, A., & Widiastuti, I. (2021). Developing computational thinking ability in early childhood education: the influence of programming-toy on parent-children engagement. *International Journal of Pedagogy and Teacher Education, 5(1),* 19. https://doi.org/10.20961/ijpte.v5i1.44397

Carriço, G. (2018). The eu and artificial intelligence: a human-centred perspective. *European View, 17(1),* 29-36. https://doi.org/10.1177/1781685818764821

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

Chen, W., Huang, C., & Chen, K. (2020). Artificial intelligence in education: from potential to practice. *Educational Technology & Society, 23(3),* 24-36.

Chen, X., & Gutmann, G. (2019). Deep learning by doing: The NVIDIA deep learning institute and university ambassador program. *The Journal of Computational Science Education, 10*(1), 93–99. https://doi.org/10.22369/issn.2153-4136/10/1/16

Cook, K., Bush, S., Cox, R., & Edelen, D. (2020). Development of elementary teachers' science, technology, engineering, arts, and mathematics planning practices. *School Science and Mathematics, 120(4),* 197-208. https://doi.org/10.1111/ssm.12400

DeJarnette, N. (2018). Implementing steam in the early childhood classroom. *European Journal of Stem Education, 3(3).*https://doi.org/10.20897/ejsteme/3878

Delcker, J. (2024). First-year students' ai-competence as a predictor for intended and de facto use of ai-tools for supporting learning processes in higher education. *International Journal of Educational Technology in Higher Education, 21(1).*https://doi.org/10.1186/s41239-024-00452-7

Ece, N. (2024). Yapay zeka: denizcilik sektöründe kullanımı ve swot analizi. *Mersin Üniversitesi Denizcilik Ve Lojistik Araştırmaları Dergisi, 6(1),* 30-51. https://doi.org/10.54410/denlojad.1491372

Elçiçek, M. (2024). Öğrencilerin yapay zeka okuryazarlığı üzerine bir inceleme. *Bilgi Ve İletişim Teknolojileri Dergisi, 6(1),* 24-35. https://doi.org/10.53694/bited.1460106

Erol, A. (2023). STEAM eğitimi sürecinde okula hazır oluş. *Uluslararası Eğitim Bilimleri Dergisi, 10 (36),* 298-325.

Garner, P., Gabitova, N., Gupta, A., & Wood, T. (2017). Innovations in science education: infusing social emotional principles into early stem learning. *Cultural Studies of Science Education, 13(4),* 889-903. https://doi.org/10.1007/s11422-017-9826-0

Gunarti, W., Pujianti, Y., & Syarah, E. (2020). Steam to r-slamet modification: an integrative thematic play based learning with r-slamets content in early child-hood education. *Jpud - Jurnal Pendidikan Usia Dini, 14(2),* 262-274. https://doi.org/10.21009/jpud.142.05

Henze, J., Schatz, C., Malik, S., & Bresges, A. (2022). How might we raise interest in robotics, coding, artificial intelligence, steam and sustainable development in university and on-the-job teacher training?.*Frontiers in Education, 7.*https://doi.org/10.3389/feduc.2022.872637

Hsiao, P.,& Su, C. (2021). A study on the impact of steam education for sustainable development courses and its effects on student motivation and learning. *Sustainability, 13(7),* 3772. https://doi.org/10.3390/su13073772

Hsu, T., Abelson, H., Lao, N., & Chen, S. (2021). Is it possible for young students to learn the ai-steam application with experiential learning?.*Sustainability, 13(19),* 11114. https://doi.org/10.3390/su131911114

Huang, J., Saleh, S., & Liu, Y. (2021). A review on artificial intelligence in education. *Academic Journal of Interdisciplinary Studies, 10(3),* 206. https://doi.org/10.36941/ajis-2021-0077

Ishaaq, N. (2023). Re: investigating the impact of innovative ai chatbot on post-pandemic medical education and clinical assistance: a comprehensive analysis. *Australian and New Zealand Journal of Surgery, 94(3),* 494-494. https://doi.org/10.1111/ans.18721

Johnston, K.,& Kervin, L. (2022). Stem, steam and makerspaces in early childhood: a scoping review. *Sustainability, 14(20),* 13533. https://doi.org/10.3390/su142013533

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

Kim, N.,& Kim, M. (2022). Teacher's perceptions of using an artificial intelligence-based educational tool for scientific writing. *Frontiers in Education, 7.*https://doi.org/10.3389/feduc.2022.755914

Klímová, B., Pikhart, M., & Kacetl, J. (2023). Ethical issues of the use of ai-driven mobile apps for education. *Frontiers in Public Health, 10.*https://doi.org/10.3389/fpubh.2022.1118116

Koul, R., Lerdpornkulrat, T., & Poondej, C. (2022). Generative AI in STEAM education: Bridging creativity and technology. *Journal of Educational Research, 115(2),* 178-194.

Liu, Y. (2023). Implications of generative artificial intelligence for the development of the media industry. *AEI, 1(1),* 29-36. https://doi.org/10.54254//1/2023006

Luo, Q. (2023). The influence of ai-powered adaptive learning platforms on student performance in chinese classrooms. *Journal of Education, 6(3),* 1-12. https://doi.org/10.53819/81018102t4181

Ma, C. (2022). Generated artificial general intelligence—The philosophical principle of artificial general intelligence and give an example. *Available at SSRN 4224423.*https://doi.org/10.14293/s2199-1006.1.sor-.pph6xzb.v2

Marar, H. W. (2024). Advancements in software engineering using AI. *Computer Software and Media Applications, 6*(1), 3906. https://doi.org/10.24294/csma.v6i1.3906

Niu, S., Luo, J., Niemi, H., Li, X., & Lu, Y. (2022). Teachers' and students' views of using an ai-aided educational platform for supporting teaching and learning at chinese schools. *Education Sciences, 12(12),* 858. https://doi.org/10.3390/educsci12120858

Pan, J. (2024). AI-driven English language learning program and academic writing integrity in the era of intelligent interface. *English Language Teaching and Linguistics Studies, 6*(4), 120. https://doi.org/10.22158/eltls.v6n4p120

Relmasira, S. (2023). Fostering ai literacy in elementary science, technology, engineering, art, and mathematics (steam) education in the age of generative ai. *Sustainability, 15(18),* 13595. https://doi.org/10.3390/su151813595

Russell, S.,& Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.

Semwaiko, G. S., Chao, W., & Yang, C. (2024). Transforming K-12 education: A systematic review of AI integration. *International Journal of Educational Technology and Learning, 17*(2), 43–63. https://doi.org/10.55217/101.v17i2.847

Sevgen Abacı, H.,& Tüzün, Ü. N. (2023). Özel Yetenekli Öğrencilerin Eğitiminde Bilim ve Sanat Entegresi. *Bilim Armonisi, 5(2),* 32-38. https://doi.org/10.37215/bilar.1144744

Sincar, M. (2023). Yapay zekâ bağlamında okul liderlerini bekleyen zorluklar. *Mustafa Kemal Üniversitesi Eğitim Fakültesi Dergisi, 7*(12), 74–85. https://doi.org/10.56677/mkuefder.1407065

Smyrnaiou, Z. (2023). Ethical use of artificial intelligence and new technologies in education 5.0. *JAIMLD, 1(4),* 119-124. https://doi.org/10.51219/jaimld/anastasios-liapakis/15

Spyropoulou, N. (2023). Augmenting the impact of steam education by developing a competence framework for steam educators for effective teaching and learning. *Education Sciences, 14(1),* 25. https://doi.org/10.3390/educsci14010025

Tsupros, N., Kohler, R., & Hallinen, J. (2009). *STEM education: A project to identify the missing components.* Intermediate Unit, 1, 11-17.

Tüzün, U.,& Tüysüz, C. (2018). Eğitimde stem + a yaklaşımı: fen eğitiminde steam uygulamaları. In *Fen ve Matematik Eğitiminde Araştırma ve Uygulamalar* (pp. 186-202).

Vafadar, M.,& Amani, A. M. (2024). Academic education in the era of generative artificial intelligence. *Journal of Electronics and Electrical Engineering,* 110-124. https://doi.org/10.37256/jeee.3120244010

Vasconcelos, M.,& Santos, R. (2023). Enhancing stem learning with chatgpt and bingchat as objects to think with: a case study. *Eurasia Journal of Mathematics Science and Technology Education, 19(7),* em2296. https://doi.org/10.29333/ejmste/13313

Vicente, F., Llinares, A., & Sánchez, N. (2020). "Sustainable city": a steam project using robotics to bring the city of the future to primary education students. *Sustainability, 12(22),* 9696. https://doi.org/10.3390/su12229696

Wahyuningsih, S., Nurjanah, N., Rasmani, U., Hafidah, R., Pudyaningtyas, A., & Syamsuddin, M. (2020a). Steam learning in early childhood education: a literature review. *Ijpte International Journal of Pedagogy and Teacher Education, 4(1),* 33. https://doi.org/10.20961/ijpte.v4i1.39855

Wahyuningsih, S., Pudyaningtyas, A., Nurjanah, N., Dewi, N., Hafidah, R., Syamsuddin, M., … & Sholeha, V. (2020b). The utilization of loose parts media in steam learning for early childhood. *Early Childhood Education and Development Journal, 2(2),* 1. https://doi.org/10.20961/ecedj.v2i2.46326

Wardat, Y., Tashtoush, M., AlAli, R., & Jarrah, A. (2023). Chatgpt: a revolutionary tool for teaching and learning mathematics. *Eurasia Journal of Mathematics Science and Technology Education, 19(7),* em2286. https://doi.org/10.29333/ejmste/13272

Wu, D., Xiang, Y., Wu, X., Yu, T., Huang, X., Zou, Y., … & Liu, Z. (2020). Artificial intelligence-tutoring problem-based learning in ophthalmology clerkship. *Annals of Translational Medicine, 8(11),* 700-700. https://doi.org/10.21037/atm.2019.12.15

Yazıcı, S. Ç., & Erkoç, M. (2023). Fen bilimleri grubu öğretmenlerinin uzaktan eğitim sürecinde yapay zekâ kullanma durumlarının analizi. *Dokuz Eylül Üniversitesi Buca Eğitim Fakültesi Dergisi, 58*, 2682–2704. https://doi.org/10.53444/deubefd.1316144

Yilmaz, Y., Yılmaz, D., Yıldırım, D., Korhan, E., & Kaya, D. (2021). Yapay zeka ve sağlıkta yapay zekanın kullanımına yönelik sağlık bilimleri fakültesi öğrencilerinin görüşleri. *Süleyman Demirel Üniversitesi Sağlık Bilimleri Dergisi, 12(3),* 297-308. https://doi.org/10.22312/sdusbed.950372