Chapter 8

STEM and AI Integration in Early Childhood: First Steps for Future Scientists

Çağrı Avan[1]

Bahattin Aydinli[2]

Abstract

This chapter examines the importance of integrating artificial intelligence (AI) and STEM (Science, Technology, Engineering, and Mathematics) in early childhood education, highlighting how this integration contributes to foundational skill development in young children. AI's role in education is emphasized through its ability to provide interactive and personalized learning experiences, thereby fostering independent learning processes among students. Integrating AI tools in early learning increases children's interest in STEM subjects and supports teachers in various instructional tasks. The chapter presents three main paradigms of AI-based STEM education: AI-directed, AI-supported, and AI-empowered STEM education. These models serve distinct functions in the learning process, such as as automating access to information, providing real-time feedback, and creating student-centered learning environments. Specifically, natural language processing tools like ChatGPT support students' individualized learning paths by offering instant information on STEM topics and assisting teachers in preparing educational materials. A practical example, "Plant Exploration with a Smart Assistant," demonstrates a model for enhancing children's scientific observation skills and environmental awareness through AI. This activity enables young learners to explore nature with the support of AI, illustrating the potential of educational technologies in early childhood education. Finally, the chapter underscores AI's contribution to the development of critical thinking and creativity skills. AI's capabilities in providing instant feedback and accessible information encourage in-depth learning experiences in STEM education, equipping students with a more informed approach to data analysis and knowledge evaluation.

1 Dr., Kastamonu Measurement and Evaluation Center, cagriavan@gmail.com, 0000-0002-4068-7631

2 Prof. Dr., Kastamonu University, baydinli@gmail.com, 0000-0002-6525-4162

https://doi.org/10.58830/ozgur.pub534.c2202

1. Introduction

AI concepts can be traced back historically to ancient myths, for example the Greek figure of Talos, who can be seen as a form of artificial intelligence (Mayor, 2018; Sheikh et al., 2023). The term "artificial intelligence" was first officially coined in the 1950s with the idea of machines simulating human intelligence (Bini, 2018); however, the definition of this rapidly evolving technology is vague and fluid (Murdick, 2020). Kaplan and Haenlein (2019) define AI as a system that can accurately interpret external data, learn from it and flexibly adapt to achieve specific goals.

AI in education is seen as a versatile tool that supports teachers. For example, it can perform time-consuming tasks such as automating student assessments, scoring, and adapting instruction to student needs (Bryant et al., 2020). According to Matzakos et al. (2023), AI tools can complement teachers, enabling them to guide students to explore knowledge independently. However, the widespread availability of AI tools has led to calls for limitations in some educational settings due to concerns about content production (Maoet et al., 2024).

Despite the broad educational potential of AI, research on its use in preschool education is limited. Several studies highlight that tools that develop practical AI projects, especially "Learning ML" or personalized learning experiences for preschoolers, such as the smart game "Maya", offer interactive and age-appropriate experiences by increasing children's engagement (Rodríguez-García et al., 2021; Akdeniz & Özdinç, 2021). Such tools reveal the role of AI in fostering interest in STEM-related topics and its importance in preschool education.

2. The Role of STEM and Artificial Intelligence in Preschool Education

The integration of artificial intelligence (AI) technologies in STEM education constitutes significant advantages in several studies. Okonkwo and Ade-Ibijola (2021) address the opportunities offered by these technologies, while Khosravi et al. (2023) highlight the benefits offered by chatbots, such as continuous access and scalability. Such tools can increase interactivity, personalization, educator support, and student understanding for those who require additional support in the STEM field. ChatGPT in particular has attracted attention as an educational tool due to its natural language communication capabilities; users can interact without programming knowledge (Baidoo-Anu & Owusu Ansah, 2023; George & George, 2023).

The fact that it reached 100 million users in just two months shows how much interest it has gained among students (Wu et al., 2023).

By using GPT-based NLP techniques to provide human-like responses, ChatGPT offers instant information for teachers and students and provides personalized learning experiences in STEM subjects (Wang et al., 2023; Verma, 2023). Teachers can enhance their teaching effectiveness by using ChatGPT for lesson planning and material development (Koraishi, 2023; Van Den Berg & du Plessis, 2023). It also helps students develop problem-solving abilities in the STEM field and its accessibility on various digital platforms facilitates learning anytime and anywhere (Rahman & Watanobe, 2023; Vasconcelos & Santos, 2023). The goals of early childhood STEM education include supporting language development, increasing interest and motivation in STEM subjects, developing problem-solving skills, and promoting individualized learning (Uğraş & Genç, 2018; Wan et al., 2021). ChatGPT's interactive features can support these goals; for example, they can improve language skills and increase students' interest and motivation by providing them with appropriate learning experiences.

3. STEM and Artificial Intelligence Supported Learning Environments and Integration

By focusing on the paradigmatic shifts that artificial intelligence has brought about in STEM (Science, Technology, Engineering, Mathematics) education, it directly impacts how the use of AI in education is transforming in the context of research, practice and technology. There are three main paradigms for how AI can be integrated into teaching and learning environments.

3.1.AI-Directed STEM Education

The AI-directed education paradigm is a behaviorism-based approach where students act as a passive receiver and AI directs the teaching process. In this paradigm, AI determines the student's learning path and progressively guides the learning process. For example, the Stat Lady Intelligent Tutoring System automates the learning process by presenting students with statistics course content in a sequential manner, expecting a specific response (Shute, 1995). Similarly, systems such as Cognitive Tutors provide students with ways to solve problems using a variety of knowledge representations and help students reinforce a particular topic (Koedinger et al., 1997). AI-directed STEM education offers a model where students follow a specific learning objective and reinforce knowledge through predetermined activities. In this model, students progress in the learning process by following the steps

determined by the AI. For example, the Stoichiometry Tutor, developed by McLaren and colleagues, supports students in learning chemistry, enabling student development on a predefined learning path (McLaren et al., 2011)

3.2. AI-Supported STEM Education

AI-supported STEM education creates a social learning environment where the learner collaborates with AI as an active participant. The social constructivist theory on which this paradigm is based emphasizes that learning takes place through social interactions (Bandura, 1986). In this context, AI acts as a tool that supports the student's learning process and is in constant interaction with the student. For example, the natural language processing tool developed by Gerard et al. analyzes students' scientific explanations and provides real-time feedback, allowing the teacher to monitor student performance (Gerard et al., 2019).

Under this paradigm, a student-centered learning environment is created and AI allows the student to individualize his/her learning process. This continuous interaction that optimizes the student's learning process has an important place in the context of STEM education. AMOEBA, a tool developed by Berland and colleagues, allows students to collaborate in real time in programming courses, analyzes students' programming processes and provides an interactive learning environment (Berland et al., 2015).

3.3. AI-Empowered STEM Education

AI-empowered STEM education offers a complex, multifactorial learning environment where the student and teacher collaborate with AI. In this paradigm, students manage their own learning process with the feedback provided by AI and become active learning leaders. In this process, AI supports students' direct involvement in learning processes by providing high transparency, more accurate feedback and personalized advice (Riedl, 2019). For example, the Lumilo glasses developed by Holstein et al. allow teachers to monitor student learning processes in real time. This AI-powered device helps teachers analyze students' interactions in the classroom and provide support based on this data (Holstein et al., 2019).

4. Practical Application Examples: STEM Based Artificial Intelligence Activities

STEM applications require the individual to use many disciplines together. In this process, the individual will be able to solve the problems experienced in daily life by using science, technology, mathematics and

engineering skills. Developing technologies directly affect this process. Artificial intelligence has recently started to be effective in our lives. An activity that can be implemented in the classroom in the context of STEM-based artificial intelligence activities is presented below.

"Plant Discovery with Smart Assistant"

Aim of the activity: To enable children to learn the basic characteristics of plants, to arouse their interest in knowing and exploring the environment and to develop their scientific observation skills.

Age Group: 4-6 years (preschool)

Duration: 30-40 minutes

Required Ingredients:

- Tablet or phone (equipped with an artificial intelligence app that can recognize plants)
- Real plants that children can observe (simple plants grown in the classroom or leaves, flowers, etc. brought for the activity)
- A simple drawing or activity sheet on which children can take notes (so they can draw the shapes of the leaves)

Event Flow:

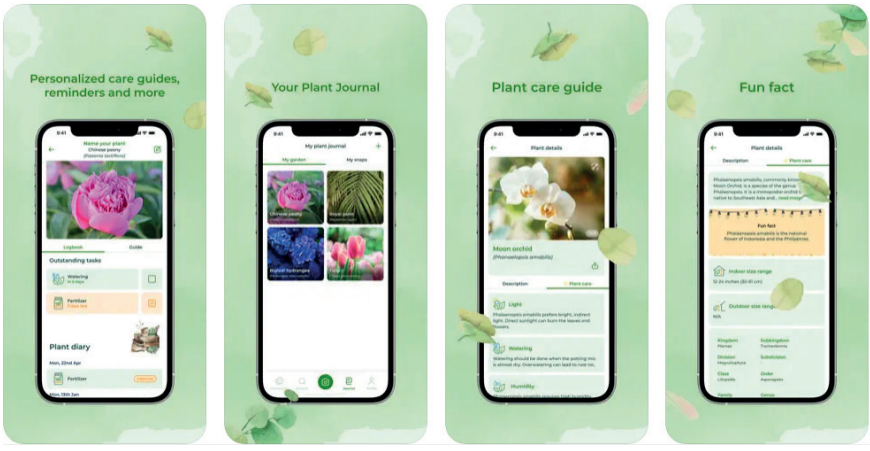
1. **Introduction and Preparation (5 minutes)**
    - Tell the children that today they will learn about plants with the help of a "Smart Assistant".
    - Give each child a plant leaf or a small potted plant.
    - Explain that the Smart Assistant will help them recognize plants and the AI will provide information about them.
2. **Recognizing and Observing Plants (10-15 minutes)**
    - Ask the children to take each plant in their hands and pay attention to the leaves, flowers or roots.
    - Identify plants with children using an AI app on a tablet or phone. When children point to their plants, the app can explain aloud the name of the plant, its characteristics and where it grows.
    - Each child can draw on paper the main characteristics of the plant they are observing or paint its colors.
3. **Plant Care and Environmental Awareness (5-10 minutes)**

- Explain to the children what plants need to grow (water, sunlight, etc.) and the importance of the environment.
- Talk about how AI can help with a plant's needs, such as the amount of water or light it needs. Encourage children to think with questions such as, "Our Smart Assistant says this plant loves the sun, what can we do?"

4. **Conclusion and Discussion (5 minutes)**
   - Ask the children again the names and characteristics of the plants they have discovered and summarize this information together.
   - Ask children questions like "What other plants would you like to explore?" or "What would you like to ask the Smart Assistant to find out more about another plant?". This way you can keep their curiosity alive.

In addition to providing children with basic knowledge about plants, this activity will be effective in giving them the first ideas about how AI can be used in scientific discoveries. Children can see AI as a "science friend" that helps them in their discoveries and start to gain environmental awareness. With this activity, children can make science-based observations through AI and increase their interest in the environment while learning about plants. Some artificial intelligence applications that can be used in this process are presented below.

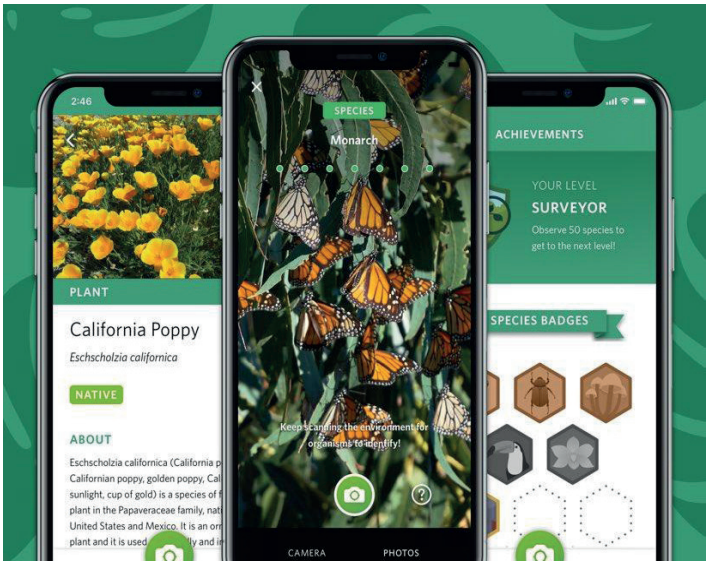
PlantSnap



Visual 1. Content Visuals for PlantSnap Application (URL-1)

- **Features:** An app that can quickly recognize plant species. Thanks to its AI-powered algorithm, it can identify plants, flowers, leaves, trees and even more exotic plants like cacti.
- **Child Friendly Use:** Provides the child with short and simple information after identifying the plants, making it easy for preschoolers to understand.
- **Advantages:** The app not only identifies the plant, but also provides plant care tips and helps children learn about the needs of plants.

Seek by iNaturalist



Visual 2. Content Visuals for Seek by iNaturalist Application (URL-2)

- **Features:** Developed in collaboration with National Geographic and iNaturalist, this app is an AI-powered identification tool that can be used to identify plant and animal species encountered in nature.
- **Child Friendly Use:** Although it does not provide detailed information, it encourages children to observe nature and allows them to explore the environment in a safe environment.
- **Advantages** It has a safe and simple interface for children; it keeps children's sense of curiosity alive with reward systems such as games.

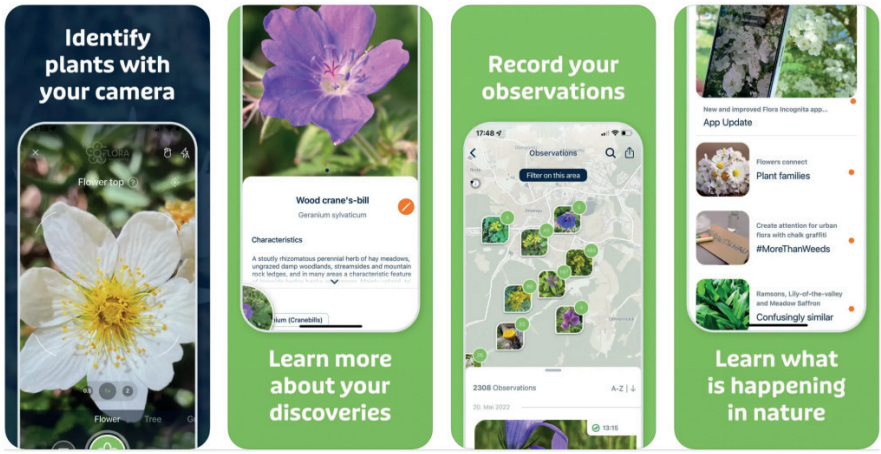
PictureThis



Visual 3. Content Visuals for PictureThis Application (URL-3)

- **Features:** With a highly sophisticated artificial intelligence algorithm for plant identification, this app offers information on the growing and care conditions of each plant, as well as identifying plant species.
- **Child Friendly Use:** Thanks to its simple interface, it is an application that children can use easily. It provides short, child-friendly information about plants.
- **Advantages:** The inclusion of information on plant care can support children's ability to take care and responsibility for plants.

Flora Incognita



Visual 2. Content Visuals for Flora Incognita Application (URL-4)

- **Features:** Flora Incognita is an AI-powered application that can quickly recognize plant species. It has a large database of plants, especially European plants, and can identify different plant parts such as leaves, flowers, stems.
- **Child Friendly Operation:** It has a simple and straightforward interface. It offers a fun process when photographing plants and is visually engaging for children.
- **Advantages:** The app helps children gain basic botanical knowledge by providing brief information about the characteristics of plants. It also allows children to learn about plants native to the local ecosystem to increase their environmental awareness. It has a safe content developed for educational use.

When artificial intelligence tools are examined, it is seen that each of them stands out with different aspects. At this point, it is important to select applications in accordance with the sub-objectives in the activity process.

5.Development of Critical Thinking and Creativity in Children Supported by STEM and Artificial Intelligence

While AI facilitates access to information in STEM education, it also improves students' analytical, synthesis and data evaluation skills. The functioning of AI as a critical tool in this process promotes a deep

understanding of concepts in the STEM field and active engagement of students in the learning process (Baisova, 2024).

The integration of AI into STEM education contributes positively to the development of critical thinking. Critical thinking is a very important skill in terms of problem solving and innovation, which includes the process of analyzing, evaluating and interpreting information. STEM education offers a structure that supports critical thinking due to the need for analytical thinking. Therefore, AI supports the development of critical thinking skills in the STEM field and helps students detect logical errors and recognize biases (Baisova, 2024)(the-impact-of-artificia...).

AI also enables students to develop the ability to evaluate alternatives by providing simulations and virtual laboratories within STEM education that allow them to test different hypotheses. In this way, students have the opportunity to see the consequences of their decisions and analyze various approaches, which helps them make more informed decisions in the problem-solving process (Ruiz-Rojas et al., 2024)

AI-based adaptive learning systems provide a personalized learning experience by delivering educational materials based on each student's knowledge level and learning style. These systems analyze the student's achievement based on their learning preferences and offer additional resources as needed. For example, if a student is found to be struggling with a particular subject, the system suggests additional videos or interactive exercises appropriate to the student's level (Cheng, Tan & Tan, 2023). This contributes to the development of critical thinking skills and allows students to evaluate their own learning process.

The instant feedback features offered by AI enable students to quickly recognize logical errors and develop critical thinking skills. For example, AI-based platforms can point out logical flaws when analyzing students' work and encourage students to revise their mistakes. Thus, students strengthen their critical evaluation habits by examining their own arguments more deeply (Nagaraj et al., 2023).

AI's ability to provoke questions and curiosity is another element that encourages critical thinking. By posing provocative questions to students, AI encourages them to analyze and research topics in more depth. This interaction makes students more interested in learning and develops their research skills (Ruiz-Rojas et al., 2024). It also promotes an interdisciplinary approach, developing the ability to integrate knowledge from different fields and allowing students to see the big picture (Bushuev, 2024).

6.Conclusion and Recommendations

Artificial intelligence (AI)-supported STEM education has significant potential to increase the speed of access to information, personalize the learning process and develop students' critical thinking skills. These technologies complement traditional learning methods, enabling students to understand complex scientific concepts, develop analytical thinking skills and transform their knowledge into practical solutions. In particular, AI tools used from early childhood onwards support children's sensitization to the environment, develop a predisposition for scientific thinking and strengthen their problem-solving abilities. In this process, AI stands out as a "learning friend" that allows students to conduct logical analysis, develop hypotheses and try different solutions.

Another contribution of AI to educational environments is that it increases students' creative thinking capacities. AI-supported simulations and virtual laboratories expand the boundaries of learning by offering students the opportunity to experiment in a safe environment. These tools both enable students to put theoretical knowledge into practice and encourage them to learn by making mistakes. For example, AI-based adaptive learning systems make learning more effective for each individual by providing a personalized educational experience according to the learning pace of students. Thanks to such technologies, students have access to additional resources to fill their gaps, while they have the opportunity to gain more in-depth knowledge in their areas of strength.

However, despite all these advantages AI offers, there are also some limitations and risks associated with its applications in education. In particular, excessive automation can lead to a weakening of students' independent thinking and problem-solving abilities. Moreover, students' dependence on technology may negatively affect their capacity to think critically and generate original ideas. Therefore, it is important to define the role of AI in education as a "helper" that supports but does not replace students. The aim of education should be to develop students' creative and critical thinking skills by using AI as a tool.

This holistic approach enables students not only to access existing knowledge, but also to learn to question and interpret this knowledge through a critical filter. AI applications in education contribute to the development of students as conscious, responsible and creative individuals integrated with technology. Thus, it is aimed that they become individuals who develop the skills to produce solutions to the challenges they will face in a rapidly changing world. Accordingly, AI-supported STEM education

stands out as a powerful tool for students to acquire 21st century skills such as analytical thinking, problem solving and creativity.

Recommendations:

1. **Develop Comprehensive Education Programs:** Programs using STEM-based AI tools should be developed from an early age. These programs can encourage critical thinking and creativity by allowing students to experience both scientific concepts and AI technologies.
2. **AI Training for Trainers:** Educators should be provided with the necessary training to be able to use AI-based tools effectively. Teachers who understand the functionality of AI technology can adapt these tools to the individual needs of students.
3. **Ensuring Fairness of Access:** AI-supported STEM education opportunities should be expanded to provide equal access to all students. It is important to address inequalities in access to technology through digital resource access projects.
4. **Establishing Data Privacy and Security Policies:** Data privacy issues arising from the use of AI in education should be addressed and measures should be taken to protect students' personal information.
5. **Developing Applications that Support Creativity and Critical Thinking:** AI applications to be used in education should have features that will nurture students' sense of curiosity, improve their problem-solving skills, and increase their creative thinking capacities. These applications can support creative thinking by providing students with the opportunity to ask questions, develop hypotheses and test various solutions.

7. References

Akdeniz, M., & Özdinç, F. (2021). Maya: An artificial intelligence-based smart toy for preschool children. *International Journal of Child-Computer Interaction, 29*, 100347. https://doi.org/10.1016/j.ijcci.2021.100347

Baidoo-Anu, K., & Owusu Ansah, I. (2023). ChatGPT as an educational tool in STEM learning. *Educational Technology Research and Development, 71*(2), 233-250.

Baisova, G. (2024). The impact of artificial intelligence on the development of critical thinking in the process of learning STEM disciplines. *Cold Science, 8*, 47-55. https://coldscience.ru

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall.

Berland, M., Davis, D., & Smith, C. P. (2015). AMOEBA: Designing for collaboration in computer science classrooms through live learning analytics. *International Journal of Computer-Supported Collaborative Learning, 10*(4), 425-447. https://doi.org/10.1007/s11412-015-9217-z

Bini, S. A. (2018). Artificial intelligence, machine learning, deep learning, and cognitive computing: What do these terms mean, and how will they impact health care? *Journal of Arthroplasty, 33*(8), 2358-2361. https://doi.org/10.1016/j.arth.2018.02.067

Bryant, J., Heitz, C., Sanghvi, S., & Wagle, D. (2020). How artificial intelligence will impact K-12 teachers. McKinsey & Company.

Bushuev, S. (2024). Application of AI for monitoring and optimizing IT infrastructure: Economic prospects for implementing predictive analytics in enterprise operations. *International Journal of Humanities and Natural Sciences, 8*(3), 125-128.

Cheng, E., Tan, A. L., & Tan, S. S. (2023). Exploring the use of emerging technologies in schools: A review of artificial intelligence and immersive technologies in STEM education. *Journal of STEM Education Research, 6*(3), 385-407.

Ellis, M. (2022). Forgotten voices: A research study of STEM educators in North Carolina on integrating global education.

Erkenkizi, D. (2024). Economic and social consequences of online education for children from low-income families in the context of digital inequality. *Innovacionnaya Nauka, 9*(1), 127-131.

George, M., & George, R. (2023). Language accessibility in education: ChatGPT's impact. *International Journal of Educational Research, 118*, 102-114.

Gerard, L., Kidron, A., & Linn, M. C. (2019). Guiding collaborative revision of science explanations. *International Journal of Computer-Suppor-*

ted Collaborative Learning, 14(3), 291-324. https://doi.org/10.1007/s11412-019-09298-y

Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-designing a real-time classroom orchestration tool to support teacher-AI complementarity. *Journal of Learning Analytics, 6*(2), 27-52. https://doi.org/10.18608/jla.2019.62.3

Kaplan, A., & Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Business Horizons, 62*, 15-25. https://doi.org/10.1016/j.bushor.2018.08.004

Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8*(1), 30-43.

Koraishi, A. (2023). Utilizing ChatGPT for lesson planning and material development. *Teaching and Teacher Education, 116*, 103-110.

Khosravi, H., Ahmad, N., & Shahid, A. (2023). Educational advantages of chatbots in STEM education. *International Journal of Interactive Mobile Technologies, 17*(2), 45-60.

Mao, J., Chen, B., & Liu, J. C. (2024). Generative artificial intelligence in education and its implications for assessment. *TechTrends, 68*, 58-66. https://doi.org/10.1007/s11528-023-00911-4

Matzakos, N., Doukakis, S., & Moundridou, M. (2023). Learning mathematics with large language models: A comparative study with computer algebra systems and other tools. *International Journal of Emerging Technologies in Learning, 18*(20), 51-71. https://doi.org/10.3991/ijet.v18i20.42979

Mayor, A. (2018). *Gods and Robots: Myths, machines, and ancient dreams of technology*. Princeton University Press. https://doi.org/10.2307/j.ctvc779xn

McLaren, B. M., Adams, D. M., & Mayer, R. E. (2011). Delayed learning effects with erroneous examples: A study of learning decimals with a web-based tutor. *International Journal of Artificial Intelligence in Education, 21*(1-2), 79-98.

Murdick, D. (2020). *Patents and artificial intelligence: A primer*. https://doi.org/10.51593/20200038

Nagaraj, B. K., Easwaramoorthi, K., Begum, S. R., Akila, S., & Sachdev, H. K. (2023). The growing role of artificial intelligence in higher education STEM: A critical review. *International Research Journal of Interdisciplinary Technological Innovations, 5*(5), 1-19.

Okonkwo, C., & Ade-Ibijola, A. (2021). Developments in artificial intelligence and Natural Language Processing: Opportunities for STEM education. *Journal of Educational Technology & Society, 24*(4), 1-15.

Rahman, S., & Watanobe, H. (2023). Accessibility and digital learning environments in STEM education. *Education and Information Technologies, 28*(3), 345-360.

Riedl, M. O. (2019). Human-centered artificial intelligence and machine learning. *Human-Computer Interaction, 35*(5-6), 455-474. https://doi.org/10.1080/07370024.2019.1686654

Rodríguez-García, J. D., Román-González, M., Moreno-León, J., & Robles, G. (2021). Evaluation of an online intervention to teach artificial intelligence with learningML to 10-16-year-old students. In M. Sherriff & L. D. Merkle (Eds.), *SIGCSE '21: Proceedings of the 52nd ACM Technical Symposium on Computer Science Education* (pp. 177-183). https://doi.org/10.1145/3408877.3432393

Ruiz-Rojas, L. I., Salvador-Ullauri, L., & Acosta-Vargas, P. (2024). Collaboration and critical thinking: Implementing generative artificial intelligence tools in higher education. *Sustainable Development, 16*(13), 53-67.

Sheikh, H., Prins, C., & Schrijvers, E. (2023). Artificial intelligence: Definition and background. In H. Sheikh, C. Prins, & E. Schrijvers (Eds.), *Mission AI, Research for Policy* (pp. 15-41). Springer. https://doi.org/10.1007/978-3-031-21448-6_2

Shute, V. J. (1995). SMART: Student modeling approach for responsive tutoring. *User Modeling and User-Adapted Interaction, 5*(1), 1-44.

Uğraş, F., & Genç, A. (2018). Goals of early childhood STEM education. *Journal of Early Childhood Education Research, 7*(2), 55-70.

URL-1https://apps.apple.com/us/app/plantsnapidentifyplants/id1451054346?platform=iphone

URL -2 https://www.inaturalist.org/pages/seek_app

URL -3 https://www.picturethisai.com/aboutus

URL -4 https://floraincognita.com/flora-incognita-app/

Van Den Berg, L., & du Plessis, P. (2023). Teacher effectiveness and technology integration: The ChatGPT case. *Journal of Educational Technology Systems, 51*(3), 345-360.

Vasconcelos, M., & Santos, R. (2023). Pathways for understanding STEM concepts through AI. *European Journal of Science Education Research, 10*(1), 25-40.

Verma, A. (2023). Enhancing STEM education with AI: The role of ChatGPT. *International Journal of STEM Education, 10*(1), 76-89.

Wang, J., Li, X., & Zhang, Q. (2023). NLP techniques in education: A focus on ChatGPT. *Journal of Educational Data Mining, 15*(2),