The Effectiveness of Implementation of AI Based STEM and Potential for Future Science Learning: Literature Review

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Abstract. The industrial revolution 4.0 brings the era of society 5.0 which has an impact on various aspects of life, one of which is the field of education by starting to apply the use of AI in learning. AI is very relevant to be applied to STEM-based science learning. The purpose of this study is to analyze the effectiveness of AI-based STEM implementation in science learning, analyze learning media that use AI based STEM, and analyze the ethics and potential use of AI in future science learning. The research method used is a literature study on international journal databases on ERIC, Scopus, and Springer. Based on the literature review, it was found that the implementation of AI based STEM is effective in science learning. AI can increase creativity, activeness, train technological literacy skills, train problem solving and support to generate creative ideas. There are also AI learning media that can be applied to STEM learning. In addition, the implementation of AI use in education also pays attention to the code of ethics so that the use of AI can be useful. In conclusion, AI based STEM is effective, there are AI based STEM media that have been used in science learning, and there is potential for the use of AI in science learning in the future.

Keywords: AI, STEM, AI based STEM, Science Learning

1 Introduction

The era of the industrial revolution 4.0 is characterized by the rapid development of digital technology to give birth to society 5.0 which makes it easier for humans to access information and transformations in various fields of life [1]. The digitization of technology can support goal 4 of the Sustainable Development Goals (SDGs) related to the quality of education, including in Indonesia. According to [2] education in Indonesia is far behind other countries, as the results of the Word Population Review data show that Indonesia is ranked 54th out of 78 countries included in the world education ranking. Technology-based learning will certainly have a positive impact on student learning outcomes consisting of student knowledge, skills and attitudes. One of the roles of digital technology in learning is Artificial Intelligence (AI).

Technological developments in the last 5 years have had an impact on the field of education which has begun to implement the use of AI in learning [3]. In the era of technological transformation, the application of AI plays an important role in preparing students' future. Based on the results of the 2022 Program for International Student Assessment (PISA) study, students who use ICT in learning have better performance. Therefore, it is important to implement ICT and AI in learning. Learning AI is important to understand AI concepts in preparation for future life [4].

AI is very relevant to STEM (Science, Technology, Engineering, and Mathematics) [4]. The implementation of AI based STEM in learning, especially science, can create effective and fun learning [5]. The integration of AI and STEM can make it easier for students to complete STEM projects and increase knowledge of AI literacy [6, 7, 8]. The importance of implementing AI based STEM in learning is that it can help prepare optimal learning strategies that meet the needs of students.

The current trend of science learning in the Era of Society 5.0 which is technology-based is starting to be applied in Indonesia such as the application of Augmented Reality (AR) technology in science learning [9]; the application of Virtual Reality (VR) technology in science learning [10]; and various other types of technology. This also opens up great opportunities for the implementation of AI in STEM-based science learning. According to [11] the digitalization of technology needs to be utilized in line with educational curriculum policies that integrate technology to improve the quality of learning. However, the application of AI in science learning in Indonesia is still very limited. The limited use of AI based STEM in science education is due to the uneven digital literacy skills of teachers and the low awareness of integrating technology in learning [11]. Even though the use of AI based STEM can make it easier for students to understand science material so that it can improve learning outcomes. Therefore, research with a literature review on the implementation of AI based STEM in science learning is needed. The purpose of this research is to analyze the implementation of AI based STEM in science learning, analyze learning media that use AI based STEM, and analyze the ethics of using AI in education. This research can add the literature review on AI based STEM, provide new thoughts to educators regarding the effectiveness of using AI based STEM, and its potential in science learning in the future.

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2 Method

This article uses the literature review method. The review in this article covers published research that discusses the implementation of AI based STEM in science learning. To investigate this review, a data search was conducted on international journal databases through ERIC, Scopus, and Springer related to the implementation of AI based STEM in science learning.

The steps used to investigate the implementation of AI based STEM in science learning are as follows: (1) Analyzing trends in science learning, (2) Identifying research results related to AI based STEM in education, (3) Analyzing the development of the use of AI based STEM in science learning, (5) Analyzing AI based STEM learning media in sciencelearning, (6) Identifying ethics in the application of AI.
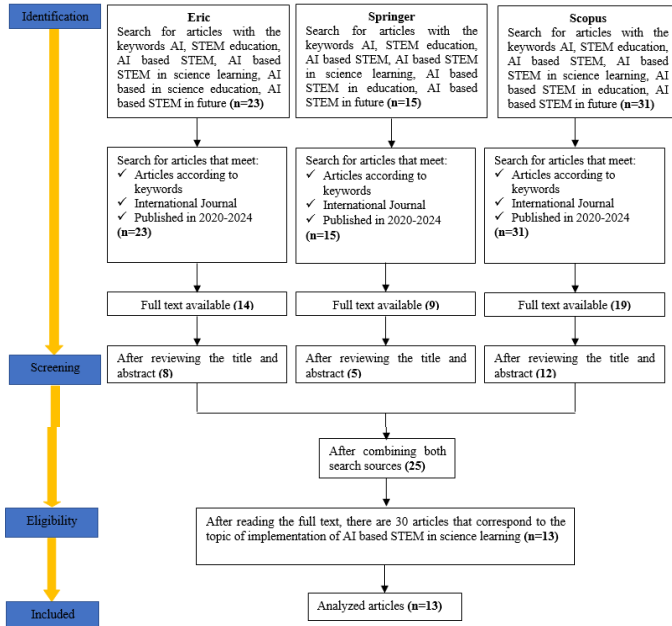

Fig. 1. Diagram of literature review research methods.

3 Results and Discussion

3.1 Effectiveness of AI-Based STEM in Science Learning

Based on the results of literature studies from previous studies, it was found that the implementation of AI based STEM was effective in science learning. The effectiveness of implementation of AI based STEM in science learning is presented in Table 1.

Table 1. Effectiveness of AI based STEM in Science Learning

No	Effectiveness of AI-based STEM in Science Learning	Studies
1.	The implementation of AI based STEM in learning effectively increases student activeness in the learning process.	[12], [13]
2.	Implementation of AI based STEM in learning is a means to train technological literacy skills.	[5]
3.	AI based STEM implementation is effective in generating many ideas and information to support STEM-based creative learning.	[3]
4.	The implementation of AI based STEM is effective in assisting problem solving in the learning process.	[14]

5.	The implementation of AI based STEM is effective and efficient in helping teachers prepare lessons. So that it can support teachers' pedagogical skills.	[15]

Some results of [15] systematic review that AI based STEM can be applied to future science learning at the elementary, middle school, and high school levels. AI is very relevant to be combined with the STEM approach in science learning.This is in line with the statement that AI is effectively applied to science learning, the combination of AI with STEM makes it easier for students to complete STEM projects and develop AI literacy skills [6, 7, 8]. The implementation of AI can innovate STEM learning, enabling collaborative personalized learning, curriculum modification, increased learning productivity, and innovative learning for the future [16]. AI and science complement each other in learning, AIhelps as a means to solve problems in learning [17]. To implement the application of AI in science learning requires educators' ability to design new learning designs and new teaching materials, as well as mastery of AI usage skills [18]. The application of AI based STEM is different from only applying AI without a STEM approach to learning. In theimplementation of science learning with AI based STEM, in addition to introducing AI, it also applies various disciplines including science, art, and technology in learning science materials [5]. In addition, differences are also shown in theimplementation of practices in science learning. Learning using AI only is more towards the practice of personalizedindividual learning according to student needs, while the application of AI based STEM is more directed towards projectlearning that requires cooperation and collaboration with teammates [4]. Another difference is shown in the assessmentaspect of the assessment used. Science learning that only implements AI only uses prototype assessment, while in learningthat implements AI based STEM, the assessment used is not only in the form of prototypes but there are projects, projectpresentations, and reflections on project activities that have been carried out [5].

Based on table 1, it can be observed that the implementation of AI based STEM is effective in increasing student engagement, practicing technological literacy skills, helping the problem-solving process, and generating ideas, as well as supporting creative learning. The implementation of AI based STEM in learning supports teachers to effectively design learning designs [19]. Teachers can adopt AI-based systems in education because they effectively support teachers' pedagogical abilities [20]. An important element in implementing technology integration in classroom learning is teacher professionalism, teachers must be able to have expertise in mastering science and technology to help improve student learning achievement [21].

3.2 The effectiveness of AI based STEM in science learning

AI based STEM is effectively used in science learning. AI is great relevant combined degan STEM approach to science learning. This matter in line with a statement that states AI is effective applied to science learning, integration between AI and STEM makes things easier student in finish STEM projects and develop ability AI literacy [6, 7, 8]. Effectiveness implementation of AI based STEM in science learning is presented in Table 2.

Table 2. Learning Media for AI Based STEM for Science Learning

Learning Media	Description	Studied By
Creation of degradable smart packaging	Manufacture of environmentally friendly food packaging and food spoilage detection tools with a coding system.	[22]
Paper cutting tool making	STEM project-based learning using AI to explain natural phenomena.	[23]
Use of augmented reality and virtual reality	Implementation of augmented reality and virtual reality in STEM-based science learning.	[24]
ARIN-561	Learning media in the form of educational games using AI based STEM.	[25]
Robobo SmartCity	Robots that can support learning by using computing and communication systems.	[26]
Chat GPT	Helps design learning, brainstorm problems, and obtain extensive learning resources.	[27], [28]

The use of AI based STEM in science learning provides a learning experience that suits the needs of students, both in the sub-disciplines of biology, chemistry, physics, and earth science. When students feel that the material taught is relevant to their needs and interests, they are more likely to be actively involved in [29]. In addition, the use of AI based STEM can achieve better learning outcomes by providing learning materials according to their understanding, students can overcome their learning difficulties, have higher-level thinking and problem-solving skills, and obtain the expected learning outcomes [30]. While in another study also mentioned that the application of AI based STEM which integrates various disciplines including science, technology, engineering, and mathematics to help students solve problems in life so that learning is meaningful.

AI based STEM has been applied to science learning. Some previous studies related to the implementation of AI based STEM include research conducted [22] by designing STEM-based science learning to make degradable food packaging innovations and food spoilage detection tools using AI technology with coding. Through this learning, learning becomes active, increases student curiosity, improves problem solving skills that exist in everyday life. Students become enthusiastic to make appropriate products for their survival by maximizing their high-level thinking, creative, innovative and collaborative skills. This is supported by computational activities that bring together programming components such as algorithm creation and code writing with interdisciplinary.

The research conducted by [23] implemented AI based STEM in science learning by making paper cutters to explain natural phenomena. Project-based learning activities by integrating different disciplines can make it easier for students to understand natural phenomena that occur in a picture illustration. When making products, students are able to implement the knowledge understood and have scientific process skills in an activity of observing, measuring, classifying, making hypotheses, conducting experiments, recording data, and concluding. Not only scientific skills, students are even able to develop engineering skills in generating ideas to find solutions by designing a product. Augmented reality (AR) and Virtual Reality (VR) technologies that are currently developed can also support science learning using AI based STEM [24]. The characteristics of science materials that are very complex and abstract are often difficult for students to understand so that the use of AR and VR can facilitate mastery of the material with object visualization.

Artificial Intelligence (AI) has revolutionized the world, becoming an indispensable force across industries, most notably in the realms of Augmented Reality (AR) and Virtual Reality (VR). AI's integration with AR and VR has transformed the way humans interact with digital environments and information. In AR, AI can improve object recognition and tracking, making digital overlays seamlessly integrate with the real world. AI-driven context awareness enhances the relevance of information displayed, adapting to user surroundings and needs. Natural language processing enables more intuitive interaction, allowing users to communicate with AR systems using voice commands or gestures. In VR, AI plays a critical role in rendering environments. AI-driven algorithms can dynamically adjust lighting, physics, and interactions in real time, leading to more immersive and realistic simulations. AI also facilitates predictive hand and body tracking, enhancing user engagement. Personalized content generation tailors VR experiences to users, ensuring they receive content aligned with their preferences and behaviors.

In addition, there are several AI based STEM learning media used, such as ARIN-561, Robobo SmartCity, and Chat GPT. ARN-561 is a game-shaped learning media that aims to introduce AI in learning and apply the concept of mathematical knowledge to learning. This game contains a game of scientists conducting an environmental expedition, but mistakenly landing on an alien planet. To get out safely from the planet, students must solve problems about the mystery of the planet and must be able to apply knowledge about AI. This game-based learning uses the Breadth Furst Search algorithm [25]. The Robobo SmartCity model is designed to introduce AI in education. This model can also be implemented in STEM learning. Robobo SmartCity is equipped with dc motor components, battery sensors, and a set of LEDs. This platform uses Bluetooth as communication access. Robobo SmartCity uses high computing and communication systems and is equipped with sophisticated actuators [26].

The next AI based STEM is ChatGPT which is an AI Chatbots that can be used in learning or assisting learning and administrative activities in Education. AI Chatbots can be used in STEM-based learning to assist in designing innovative learning [27]. ChatGPT can be used efficiently to acquire basic knowledge and skills [28]. Based on the systematic results of the literature, it is known that AI based STEM is effective in increasing student engagement, training technological literacy skills, helping the problem-solving process, and generating ideas, as well as supporting creative learning. The implementation of AI based STEM in learning supports teachers to effectively design learning [19]. Teachers can adopt AI-based systems in education because they effectively support teachers' pedagogical skills [20]. An important element in implementing technology integration in classroom learning is teacher professionalism, teachers must be able to have expertise in mastering science and technology to help improve student learning achievement [21]. There are several ways that ChatGPT can be used across the STEM spectrum:

1. **Science**: ChatGPT allows students to ask unlimited questions to formulate their own understanding of core subject matter before they enter the classroom. ChatGPT explained things in simpler language when asked to modify the responses for a middle school student.

2. **Technology**: If students are asked to complete coding assignments in their normal IDEs and then ask ChatGPT to enhance what they created, teachers can not only assess students' ability to write their own methods but also can assess if students understand exactly why the optimization tool made the suggestions.

3. **Engineering**: While having students solve problems using the engineering design process, natural language models can aid teachers in facilitating instruction. ChatGPT can speed up the process of research problems and give potential solutions that students they hadn't considered. Additionally, once students have tested designs, they can ask ChatGPT to give suggestions for improvements and redesign.

4. **Mathematics**: a discussion about the specificity of prompts and reading word problems thoroughly has always been a focus in mathematics. We can further explore this concept using ChatGPT.

The implementation of AI in education has a huge positive impact. However, there needs to be caution for students and educators in implementing AI during learning [27]. Misuse of AI can violate human rights if its use is not based on humanitarian principles. Ethical violations in using AI are a topic of discussion that is still questionable today [4]. Therefore, it is necessary to socialize the moral ethics of using AI to students and educators so that the implementation of AI in education can adhere to ethical codes and respect human rights [31]. The use of AI in STEM research is also still questionable regarding research ethics, and the copyright of a work and authorship of writing [32].

The rapid development of digital technology makes it likely that the world of education will rely on AI [33]. All future jobs will be required to be able to master intelligent machines. Therefore, it is important to equip students with AI knowledge by designing a curriculum that applies AI to learning [34]. This is because life in the future leads to mastery of technology including AI, robotics, augmented reality, and other digital technologies. The future direction is predicted that work and life will be dominated by the use of AI so it is necessary to prepare a generation of AI-literate students [15]. The implementation of AI based STEM is a bridge to be able to prepare students who can compete in life in the future. The implementation of AI based STEM will match students' interests so that it not only provides knowledge in science learning but can increase student learning motivation [35]. This learning motivation can increase student motivation for a career in AI development. In addition, AI based STEM learning involves a creative process that hones students' experiences, ideas, and intuition in solving a problem [36]. The implementation of AI based STEM is important because science education in the future is not only a transfer of knowledge but learning that trains the improvement of knowledge, attitudes, and skills in preparation for a future career [37].

4 Conclusion

AI based STEM is effective to be applied to science learning. AI based STEM can increase creativity, activeness, train technological literacy skills, as well as practice problem-solving and support to come up with creative ideas. AI learning media that can be used in implementing AI STEM-based science learning include creation of degradable smart packaging, paper cutting tool making, use of augmented reality and virtual reality, ARIN-561, Robobo SmartCity, and ChatGPT. The use of AI in the field of education is very important to prepare students for future careers in the era of increasingly massive technological transformation. However, the code of ethics in the application of AI in the field of education must still be considered. This is because the ethics of applying AI in education are still questionable, so further socialization is needed in its implementation.

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