Artificial Intelligence for Human-Technologies-Economy Sustainable Development
23–25 May 2024
Lublin, Poland
make learn
TIIM
PIConf
Management, Knowledge and Learning
International Conference
Technology, Innovation and Industrial Management
Sustainable Development

STEM Education, Artificial Intelligence, and Ethical Challenges

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Abstract

This article delves into the intersection of artificial intelligence (AI), science, technology, engineering, and mathematics (STEM) education, and ethics, highlighting their role in the promotion of responsible technology. As society increasingly relies on digital technology, ethical considerations in AI education are paramount. This study navigates ethical standards by analysing data from various institutions. The proposed scenario outlines a methodology for AI integration, focussing on responsible and sustainable use. From the Turing test to the Tong test, AI's evolution sparks debates from optimism to pessimism. This ongoing dialogue underscores the importance of human-tech interaction. Integration of AI promises innovation in STEM education. It is imperative to acknowledge AI's impact and foster dialogue for a responsible and sustainable technological future. The implementation of AI requires careful management to optimise benefits and mitigate risks. The original proposal makes a substantial contribution to the integration of AI in STEM education.

Keywords: artificial intelligence, ethical challenges, integration, interdisciplinary relationship, pilot phase, STEM education

1. INTRODUCTION

The study highlights AI's central role in shaping students' interdisciplinary thinking in STEM education, fostering cross-disciplinary skills essential for real-world challenges. AI tools create an adaptive, personalised learning environment, encouraging students to apply STEM knowledge across various contexts and tackle complex problems holistically. This approach prepares professionals to address

modern societal challenges effectively (Bianchi et al., 2024). However, the integration of AI into STEM education requires careful consideration of ethics (du Boulay, 2023). STEM education goes beyond simply providing technical skills; it promotes critical thinking, problem-solving abilities, collaboration, and creativity. STEM education encourages a multidisciplinary approach to problem-solving and gives students a comprehensive perspective on how to address complex challenges in the modern world. In essence, it develops various skills and qualities relevant to contemporary society.

Integration of AI into STEM education highlights the ethical responsibilities of advanced technologies such as AI. This is due to the inherent characteristics of AI, which operates on the basis of algorithms and machine learning and makes decisions that affect people and society.

The opaque nature of AI decision-making raises concerns about accountability, transparency, and potential bias. Therefore, it is necessary to foster an ethical responsibility culture alongside the implementation of AI. This is particularly important in the context of young minds' education because it involves the formation of future professionals who will work together and contribute to the development of AI. In STEM education, by inculcating ethical consciousness, critical thinking, and responsible use of technology, we prepare students to navigate the complexity of AI and prioritise ethical considerations. This holistic approach ensures that AI is integrated into social values and contributes to the development of a responsible and ethical generation (Xu & Ouyang, 2022).

2. PAST AND PRESENT FOR EVALUATING AI

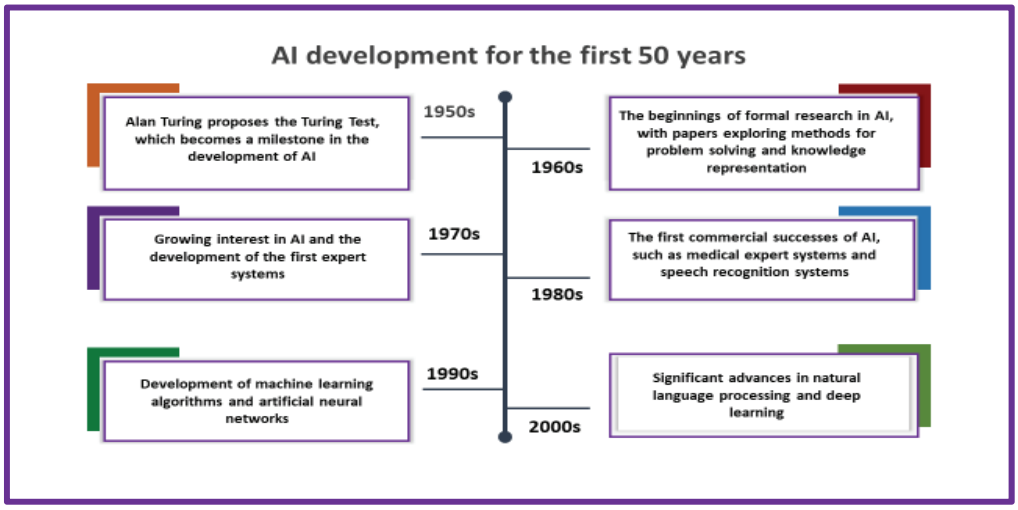
Table 1 presents definitions of concepts that can serve as a starting point to understand and further researching the concepts mentioned in the paper.

Table 1: Short description of the concepts

No. crt.	Concept	Definition
1.	STEM education	STEM education involves an integrated approach to teaching and learning in these areas, which emphasises practical application, problem-solving, and the development of key skills necessary for success in the 21st century. (Barth & Muehlfeld, 2022; Callejas et al., 2023; Freeman et al., 2014; Hamad et al., 2022; Huang et al., 2022; Li et al., 2020; Nistor et al., 2018; Norman, 2023; Peters-Burton et al., 2022)
2.	Artificial Intelligence	AI refers to the ability of a system or machine to simulate intelligent behaviour such as humans. This includes learning, solving problems, recognising patterns, and making decisions based on algorithms and data. (Kamalov et al., 2023; Käser & Alexandron, 2023; Zador et al., 2023)
3.	Ethics	Ethics refers to the study of moral principles and human behaviour and the study of why something is right or wrong (Commission, 2012). In the field of research and technology (Longo et al., 2020), ethics is a measure of the application of these principles to the development and use of technology to ensure that they are beneficial to morals and responsibility (Kamalov et al., 2023).
4.	Ethical challenges of the intersection between STEM education and AI	These include concerns about data privacy and information security (Madhloom et al., 2023) related to the collection and use of student data in AI systems (Almeida et al., 2022; Borenstein & Howard, 2021; Dignum, 2018; du Boulay, 2022; Holmes et al., 2022; Mouta et al., 2023). Other issues include the social and cultural impact of the use of AI technologies in education and the impact on human development and society as a whole (Dieterle et al., 2022; Holmes et al., 2022; Nguyen et al., 2023; Schreffler et al., 2019; Xu & Ouyang, 2022b; Yannier et al., 2020).

Alan Turing's first known article on concepts related to AI was "Computer Machinery and Intelligence", which was published in 1950 in the journal "Mind". The paper is famous for the introduction of the *Turing test*, a method proposed to evaluate machine intelligence (Picture 1).

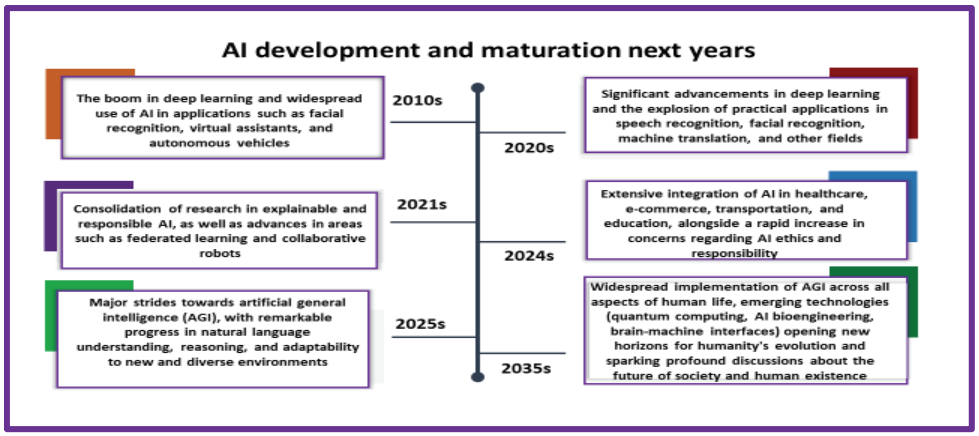
Picture 1: Presentation of the development of AI



Authors' own contribution

Although the paper does not explicitly use the term "Artificial Intelligence," Turing's work laid the groundwork for subsequent AI developments (Käser & Alexandron, 2023). Approximately 70 years later (Picture 2), Chinese researchers introduced a new methodology to evaluate general AI, called the *Tong test*. According to the Beijing Institute for General AI (BIGAI, https://eng.bigai.ai/), the Tong test goes beyond assessing whether an AI can communicate similarly to a human, as in the Turing test (Zador et al., 2023). Instead, the Tong test evaluates AI's proficiency in vision, language, consciousness, motion, and learning, incorporating a comprehensive value system encompassing physiological, survival, emotional, social, and collective aspects. BIGAI emphasised the importance of this testing approach, deeming it necessary for the seamless integration of general AI into the human environment, with a focus on practical capabilities and ethical values. All of this stems from Chinese researchers creating a *"child" named Tong Tong (Little Girl)*, the world's first AI child (Sharma, 2024).

Picture 3: Presentation of the development and maturation of AI



Authors' own contribution

3. RESEARCH GOAL AND METHODOLOGY

The research aims to explore the interaction between STEM education, AI, and ethical challenges to foster a responsible future. This approach seeks to facilitate a constructive dialogue on the integration of ethical considerations into the implementation of AI in education, ensuring its ethical and responsible use. Key components of this ongoing research include

i) a thorough literature review;
ii) an in-depth analysis of data from reports by European institutions, universities, and stakeholders in education policy;
iii) a focused examination of issues related to individual rights, data security, transparency in decision making, non-discrimination, and responsibility in AI development and utilisation.

For a vivid and in-depth understanding of researching on this paper's proposed subject, the methodology presented in Picture 3 can serve as a starting point for a future pilot project:

Picture 3: A proposed methodology framework

Authors' own contribution

Although global access to education is a larger ethical concern for humanity, this paper specifically focuses on the ethical considerations related to the integration of AI into STEM education. The objective is to contribute to the identification of ideas and strategies that advocate for the ethical and responsible use of AI in STEM learning environments. At the beginning of the 2023-2024 academic year, universities evaluated the pros and cons of AI in education (CIS, 2023). AI promises personalised learning, efficiency, and improved access to resources, but concerns persist about dependency, privacy, depersonalisation, and memory issues (Agkun & Greenhow, 2021).

The proposed methodology offers a framework to examine these relationships and improve our understanding of the integration of AI with ethical considerations in STEM education. As our research progresses, we plan to present a scenario that illustrates the integration of ethics and AI technology in educational settings aligned with our methodology. This scenario serves to highlight the benefits of using AI to embed ethics and responsibility, providing theoretical insights and practical guidance for potential implementation in educational institutions.

4. AI INTEGRATION AND IMPLEMENTATION IN STEM EDUCATION

The proposed scenario is capable of providing an innovative and interdisciplinary approach to the integration of AI into science and technology education, based on a solid theoretical foundation and a necessary ethical perspective in the digital age.

4.1. Integrating AI into STEM Education

Context of STEM Education and the transformational role of AI: In STEM education, the integration of AI is becoming increasingly important in solving the complex challenges of modern society (Bozkurt et al., 2022; Dieterle et al., 2022; du Boulay, 2022, 2023; Holmes et al., 2022; Hynes et al., 2023; Mouta et al., 2023; Nguyen et al., 2023). Examining the literature highlights the need for an interdisciplinary approach and the use of AI to optimise learning processes and prepare students for the challenges of the future (Coates et al., 2023; Kamalov et al., 2023; Nicolescu & Tudorache, 2022; Zador et al., 2023).

Integration of AI in the theoretical and pedagogical foundations of education: The proposed approach, which draws on established teaching theories such as individualised learning and constructionism, enables AI to create adaptable and personalised learning environments. Additionally, examining relevant literature from cognitive science, educational psychology, human-computer interaction, computational neuroscience, machine learning, robotics, educational technology, data science, and ethical studies in technology enhances the theoretical framework, showcasing AI's transformative potential in STEM education.

Methodological design of AI integration in STEM education: The proposed methodology unfolds in a series of coherent steps, which we will discuss further in the following sections. Where necessary, we will provide elaborate explanations to ensure clarity and thorough understanding.

- ✓ **Step 1:** At this stage, students and educational systems are identified through consultation with teachers, education specialists, and other stakeholders. Depending on contexts and assessment objectives, specific student needs may vary, including learning styles, knowledge levels, cognitive abilities, special educational needs, interests, and mental or emotional well-being;
- ✓ **Step 2:** A specific goal for integrating AI within STEM is established while teaching theories such as personal learning and construction theory are used to conceptualise the process.

Given the rapid advancement of AI and its technologies, it is important to explore their alignment with established educational theories and ethical standards. Theories such as personalised learning and constructionism are relevant in this context. Personalised learning adapts the learning process to individual student needs, potentially informing the development of machine learning systems for personalised experiences (Bandi et al., 2023; Bernacki et al., 2021; Kucirkova, 2019). Similarly, constructionism underscores active knowledge construction by individuals, suggesting parallels with AI learning from complex environments (Kucirkova, 2019). However, ethical considerations are of paramount importance, especially when it comes to problems related to the social and cultural impact of AI technology in terms of data privacy, information security, and education. These concerns include the collection and use of student data in AI systems and the broader impact on human development and society, as highlighted in references (Almeida et al., 2022; Borenstein & Howard, 2021; Dignum, 2018; Dieterle et al., 2022; du Boulay, 2022; Holmes et al., 2022; Madhloom et al., 2023; Nguyen et al., 2023;

Mouta et al., 2023; Schreffler et al., 2019; Xu & Ouyang, 2022; Yannier et al., 2020). The integration of AI in education must adhere to strong ethical principles, ensuring data protection, algorithm transparency, and equitable access to education. Therefore, the integration of educational theories with ethics can foster a sustainable and equitable educational environment. The Turing test intersects with personalised learning and constructionism, initially assessing machine communication imitation, but paving the way for AI development and human-machine interaction (Carlucci Aiello, 2016; Clivaz & Milton, 2018; Käser & Alexandron, 2023; Natale & Henrickson, 2022; Paschek et al., 2017; Zador et al., 2023). Similarly, personalised learning and construction theory emphasise individualised and active knowledge acquisition, which potentially guides AI development. For example, personalised learning principles can inform machine learning algorithms for individualised user needs, while constructionism can guide AI in building its own models from complex environments. Consequently, these theories, though originating differently, can shape AI evolution towards more personalised, interactive, and autonomous systems.

- ✓ **Step 3:** This stage involves the detailed design of AI-infused learning modules and considers adaptability, personalization, and interaction as an essential element;
- ✓ **Step 4:** Close cooperation begins with technical and educational experts to assess the feasibility and effectiveness of the scenario. Teacher feedback helps to adjust the details of practice;
- ✓ **Step 5:** Preparation of technical resources and pilot implementation: Ensure the availability of the necessary technical resources and apply scenarios at the pilot stage to evaluate the impact and adjust to feedback received.

4.2. Implementing AI integration in STEM education

The proposed scenario implementation in a real school environment

- ✓ **Step 1:** Choosing a school for the implementation of the scenario and obtaining the approval of the school administration. This phase involves evaluating the institution's existing resources and technical readiness;
- ✓ **Step 2:** Consult and work closely with teachers to familiarise them with the technical and educational concepts involved. Organisation of training sessions for teachers to ensure effective implementation;
- ✓ **Step 3:** Implementation of the pilot phase by starting to assess the effectiveness of the scenario in a controlled environment. Monitoring and collecting data on student reactions, the adaptability of the AI module, and overall performance;
- ✓ **Step 4:** Real-time adjustments and feedback collection based on feedback received during the pilot phase continuous adjustments to improve the scenario;
- ✓ **Step 5:** Scale up the implementation based on the success of the pilot phase, extend the scenario to all schools or multiple classes, and address potential challenges more broadly. Scaling up implementation refers to applying developed scenarios in a broader context after a successful pilot in a controlled environment, such as a single class or part of a school. This expansion aims to bring the same approach to a wider audience while addressing any potential challenges that may arise. Identifying and addressing problems quickly ensures effective and successful implementation at a higher level.

4.3. Integration of AI in STEM education and the challenge of institution reputation risk

In the context of the contemporary education debate, the emerging integration of AI into STEM education is bringing about a paradigm shift with profound implications, not least due to the nuanced challenge of the risk of reputation for educational institutions (Chen et al., 2020). This risk lies with the potential danger of institutions' position and respect within the educational community because of inadequate management or ethically controversial implementations of AI technologies. As in the delicate balance of a precarious narrow path, educational institutions embarking on the journey of AI integration are at the crossroads of innovation and ethical responsibility (Al Darayseh, 2023; Habbal et al., 2024; Rahiman & Kodikal, 2024; Xuejiao, 2024). Failure to navigate this terrain with precision and predictability can have negative consequences and damage the reputation and credibility of the institution. In the discourse on reputation risk, it is imperative that institutions exercise prudence and ethical awareness when adopting and deploying AI technologies. Lack of attention to ethical considerations and rapid implementation can lead to accidental consequences, invite monitoring from stakeholders, and erode the integrity of the institution. On the contrary, institutions adopting a judicious approach characterised by careful planning, stakeholder engagement, and robust ethical frameworks are better placed to mitigate reputation risk (David et al., 2022; Xu & Ouyang, 2022a). These institutions strengthen their credibility and position in the educational landscape by giving priority to the transparency, accountability, and ethical use of AI technologies. Integral to the debate on reputation risks is the recognition of their multifaceted impact on various stakeholders, in particular students, primary beneficiaries, and recipients of educational efforts (Williamson, 2024). Institutions that manage the complexity of AI integration taking good care of students' well-being and educational outcomes, not only preserve their reputation but also affirm their commitment to promoting a conducive learning environment. The concept of the risk of educational institution reputation in the context of the integration of AI in STEM education emphasises the need for institutions to be cautious and understand the complex interaction between innovation, ethics, and institutional reputation (Xu & Ouyang, 2022a). Through informed decision-making, ethical leadership, and a consistent commitment to excellence, institutions can navigate the terrain of AI integration while protecting their most valuable asset: their reputation.

5. CONCLUSION

The article highlights the reciprocal relationship between STEM education and AI, emphasising their essential connection to the realisation of human aspirations. Analysing the impact of AI on STEM education underscores the importance of continuous adaptability and interaction between the two fields.

It also explores the perspective of rapid AI evolution, which may have a more significant impact than the changes brought about by STEM education, suggesting that the current influence of STEM education on AI development may be less significant in the context of technological changes.

This approach provides a balanced view of the relationship between the two fields, emphasising the need for ongoing dialogue to ensure appropriate and synergistic progress in a rapidly evolving digital age. In summary, the future of integrating AI into STEM education is full of promise and challenges. Increasingly, technology offers us the opportunity to revolutionise learning processes, thus improving education. However, it is important to approach this progress with caution.

The associated risks, such as the lack of transparency of AI algorithms and data security issues, must be carefully managed. By adopting a responsible and ethical approach, we can ensure that the benefits

brought about by AI are sustainable and equitable for all. It is time to act with confidence and determination, using technology to build a brighter future for the education of future generations.

In the digital age, the integration of AI into STEM education is essential for sustainable futures.

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