Model-based definition design in the product lifecycle management scenario

4 STEM-CARES

STEM Community for AI Resources and Educational Strategies

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Introduction

Artificial intelligence (AI) is transforming all sectors of society, and higher education is no exception. In STEM (Science, Technology, Engineering, and Mathematics) education, AI has the potential to revolutionize teaching methodologies by enhancing personalized learning, automating assessment processes, and facilitating access to advanced knowledge (Berge & Haugsevje, 2024; Uzumcu & Acilmis, 2024). However, integrating AI into STEM education presents multiple challenges that have hindered its widespread adoption, exacerbating existing gaps in access to technology, digital literacy, and collaboration opportunities (Adeshola & Adepoju, 2024).

One of the most pressing issues is the gap in AI literacy (Chandel & Lim, 2024). Many educators lack fundamental knowledge about AI, its applications, and its impact on education, limiting their ability to leverage its pedagogical benefits. Unlike other educational innovations, AI requires technical skills and a deep understanding of its ethical implications and applicability across different educational contexts. The lack of AI literacy restricts its adoption in the classroom and leaves students unprepared for a future where AI usage will be an essential competency in their professional careers (Sperling et al., 2024).

Another significant challenge is the disparity in access to AI resources and tools. While well-funded universities and institutions have begun integrating AI tools into their curricula, others lack the necessary technological infrastructure (Michel-Villarreal et al., 2023). Limited access to

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advanced software, appropriate hardware, and AI-driven educational platforms creates disparities between those institutions able to innovate and those that remain behind. This inequality is particularly pronounced in emerging countries or regions with lower investment in STEM education, where both educators and students struggle to have access to cutting-edge technology (Bulathwela et al., 2024).

In this context, the principles of open science offer a valuable framework for addressing many of these challenges. Open and reproducible practices in education, such as the co-creation of resources, shared pedagogical strategies, and equitable access to tools, can democratize AI integration and foster a more inclusive STEM ecosystem (Azevedo et al., 2021).

A significant barrier to effective AI integration is the absence of collaborative platforms and support networks. Many educators lack opportunities to share and co-develop effective AI teaching strategies. Without a common space for exchanging knowledge and experiences, best practices are not widely adopted, and educators miss the chance to learn from advancements made by their peers in different institutions and countries (Zeller & Dwyer, 2022). Consequently, innovative efforts remain isolated, limiting their potential for large-scale impact. Open pedagogical communities – aligned with the principles of open science – offer a viable response to this challenge. By providing shared repositories, co-created resources, and peer networks, they help overcome isolation and promote inclusive and reproducible innovation in AI education (Parsons et al., 2022).

While open science offers a promising framework to address these structural challenges, cultural and perceptual barriers still hinder its implementation. Among them, resistance to change and negative perceptions of artificial intelligence remain significant obstacles. Some educators view AI with scepticism, fearing that these technologies might replace their role in the classroom or dehumanize the teaching-learning process (Chan & Tsi, 2024). There is a legitimate concern about excessive dependence on AI and the potential loss of human interaction in education, which discourages some educators from exploring its benefits. Addressing these concerns requires technical training and a clear understanding of how AI can complement and enhance teaching rather than replace it.

Another critical gap is the scarcity of continuous professional development opportunities in AI integration. Although some educators express interest in learning about AI and its applications, training programmes and ongoing education in this field remain limited (Delello et al., 2025). Many institutions lack clear strategies for training faculty in AI, restricting opportunities for upskilling and professionalization. Without proper professional development, even educators willing to adopt AI struggle to implement it effectively in their teaching practices.

From the student's perspective, the lack of AI integration in STEM education may hinder the acquisition of essential skills for the future. Automation, data-driven decision-making, and collaboration with intelligent systems are fundamental competencies in an increasingly digitalized job market. If students do not have the opportunity to interact with AI as part of their education, they will be at a disadvantage compared to those who have developed these skills in academic settings.

The relationship between these challenges and the United Nations Sustainable Development Goals (SDGs) is evident, particularly in pursuing global education and innovation objectives (Raman et al., 2024). Goal 4: ensure inclusive and equitable quality education, which is directly affected by the lack of equitable access to AI tools and the absence of structured training in their pedagogical use. Similarly, Goal 9: build resilient infrastructure and promote sustainable industrialization, is hindered by the lack of a structured AI adoption strategy in STEM education. Without effective AI integration, progress toward these SDGs is slow, and the potential of technology to bridge educational gaps remains underutilized, notably when AI integration lacks support from open collaboration frameworks that align technological innovation with educational justice (see Figure 4.1).

To address these challenges, we introduce STfEM-CARES (STEM Community for AI Resources and Educational Strategies) – a global initiative designed to support educators in effectively integrating AI into STEM education. By promoting open access to curated teaching strategies, shared ethical guidelines, and collaborative AI resources, STEM-CARES contributes to building a culture of open and equitable innovation. It also seeks to bridge existing disparities and empower a new generation of educators and learners. This chapter explores the challenges of AI integration in STEM education and outlines how STEM-CARES offers a structured, scalable, and inclusive approach to overcoming them.

Development

Theoretical framework

AI in education: A transformative technology

Artificial Intelligence (AI) transforms education by enabling personalized learning, adaptive assessments, and intelligent content delivery, resulting in more efficient and tailored learning experiences (Holmes et al., 2021; Chen et al., 2020). Integrating AI-driven technologies – such as intelligent tutoring systems, automated grading, and predictive analytics – has significantly improved student engagement, retention, and academic performance (Dede et al., 2020; Gligorea et al., 2023). These advancements allow

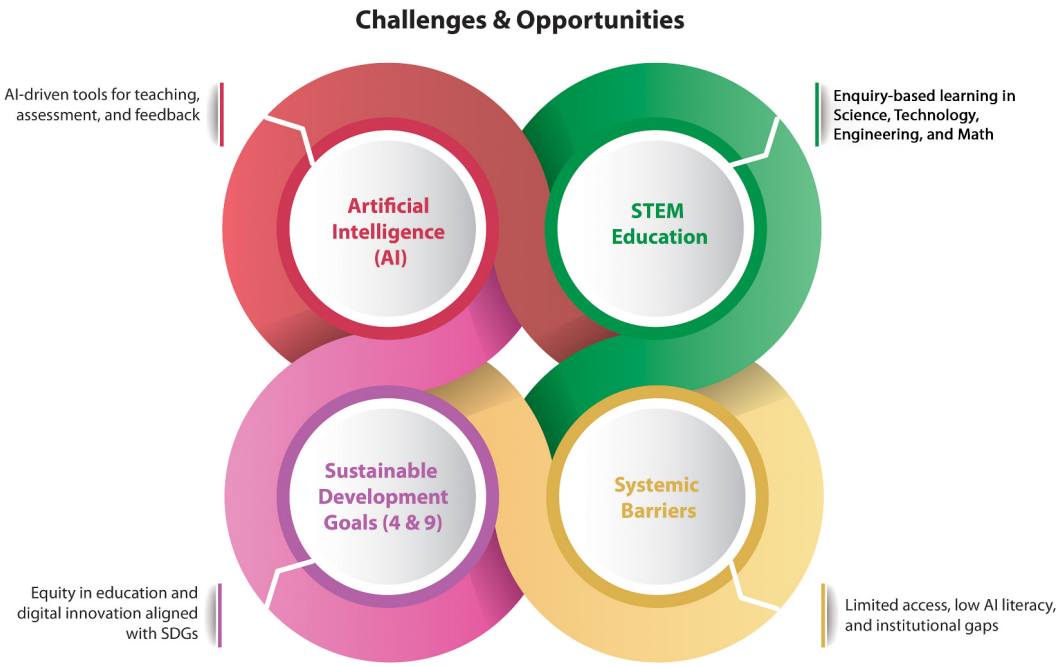

Figure 4.1 The intersection of AI, STEM education, SDGs, and systemic barriers.

educators to provide real-time feedback, identify learning gaps, and customize instructional approaches to meet individual student needs.

One of AI's most impactful educational contributions is adaptive learning, which tailors instruction based on a student's performance and learning pace. Adaptive learning platforms use AI to dynamically adjust content, ensuring students receive the appropriate level of challenge and support at every stage of their learning process (Yan et al., 2024). This personalization enhances knowledge acquisition and fosters deeper engagement in complex subjects, particularly in STEM disciplines, where iterative problem-solving and conceptual understanding are essential (Astuti et al., 2021).

Despite these advantages, the implementation of AI in education remains inconsistent. Many educators face challenges in adopting AI-driven teaching strategies due to limited technical expertise, restricted access to AI tools, and concerns about ethical implications (Al-Zahrani & Alasmari, 2025). These barriers are especially pronounced in STEM education, where AI-driven methodologies could yield the greatest benefits but are often hindered by institutional constraints, lack of professional training, and infrastructure disparities.

This raises a critical question: *How can AI be effectively leveraged to enhance STEM education while ensuring equitable access, ethical implementation, and sustainable integration into teaching practices?*

AI applications in STEM education

STEM disciplines (Science, Technology, Engineering, and Mathematics) demand interactive, dynamic, and data-driven approaches to cultivate critical thinking, problem-solving, and hands-on learning (Čubela et al., 2023). AI has the potential to bridge this gap by equipping educators with powerful instructional tools that enhance teaching effectiveness and improve student outcomes. Some of the most impactful AI applications in STEM education include:

- Intelligent Tutoring Systems (ITS): AI-powered tutors provide real-time, personalized guidance based on student responses, fostering self-directed learning and deeper conceptual understanding (Ahuja et al., 2022).
- AI-Driven Feedback and Assessment: Automated grading and natural language processing (NLP) generate instant, targeted feedback, allowing students to identify and correct misunderstandings immediately (Zawacki-Richter et al., 2019).
- Predictive Learning Analytics: AI models analyse student performance data to forecast learning outcomes and refine instructional strategies, enabling educators to address student needs proactively (Sghir et al., 2023).

Research indicates that students in AI-enhanced STEM environments exhibit higher conceptual understanding and retention rates compared to those in traditional learning settings (Yang et al., 2024). This is particularly significant in STEM education, where hands-on experimentation and iterative problem-solving are critical. AI-driven simulations and virtual labs create immersive, risk-free environments where students interact with complex scientific phenomena, fostering experiential learning and skill mastery (Luckin & Cukurova, 2019).

Despite these advantages, AI adoption in STEM education remains limited. Many educators lack access to AI tools, encounter technological infrastructure challenges, or face institutional resistance to change (Al-Zahrani & Alasmari, 2025). These obstacles raise a key question: What prevents STEM educators from fully leveraging AI, and what barriers must be overcome for broader adoption?

Challenges in AI adoption for STEM educators

While AI presents significant opportunities for STEM education, several key barriers continue to hinder its widespread adoption:

- Limited Access to AI Tools and Infrastructure: Many educational institutions, particularly in developing regions and underfunded schools, lack the necessary resources to implement AI effectively (Khan et al., 2024). High-end AI models require computational power, stable internet connectivity, and digital infrastructure, which are not universally available. Without affordable and accessible AI tools, educators struggle to integrate AI into their curricula, widening the digital divide.
- Lack of Collaborative Platforms for Educators: AI-driven teaching strategies require continuous refinement, validation, and adaptation to remain effective (Strielkowski et al., 2024). However, many educators lack access to structured platforms to share best practices, co-develop AI-enhanced pedagogies, and exchange insights. This absence of collaboration results in fragmented AI adoption, where only well-resourced institutions benefit while others remain disconnected from emerging advancements.
- Ethical and Inclusivity Concerns: AI models can reinforce biases that disadvantage specific student populations if not designed carefully. Algorithmic biases in AI-powered assessments may lead to grading disparities, while AI-driven learning platforms may overlook linguistic and cultural diversity (Xia et al., 2024). AI must be ethically designed, transparent, and inclusive to prevent unintended educational inequalities, ensuring it benefits all students equitably.

These challenges underscore an urgent need for structured AI literacy programmes that equip educators with the necessary knowledge and skills to integrate AI effectively into their teaching practices. Additionally, increasing accessibility to AI resources is essential to bridge technological gaps and ensure equitable adoption, particularly in underfunded institutions and developing regions. Equally important is implementing ethical frameworks and policies to mitigate algorithmic biases, promote inclusivity, and safeguard diverse student populations from unintended disadvantages. Addressing these barriers is crucial to ensuring that AI in STEM education remains ethical, inclusive, and aligned with pedagogical best practices, raising a fundamental question: How can we design AI-driven education systems that empower all learners while maintaining educational integrity and equality?

Ethical considerations in AI-driven education

The increasing reliance on AI in education raises concerns regarding transparency, bias, and student privacy. Algorithmic decision-making in education must be carefully managed to avoid reinforcing structural inequalities (Klimova et al., 2023; Williamson & Eynon, 2020). Ethical AI adoption in STEM education depends on:

- Bias Mitigation Frameworks: AI models should undergo rigorous testing to ensure they do not favour or disadvantage specific student groups.
- Transparent AI Algorithms: Educators must understand and interpret AI decision-making processes to avoid relying on opaque algorithms indiscriminately.
- Student Data Privacy Protections: Integrating AI into education requires handling sensitive student data. Institutions must implement strict data governance policies to ensure privacy and regulatory compliance.

Several initiatives advocate for ethical AI policies in education, emphasizing that AI should be used as an augmentative tool rather than a replacement for human educators (Miao et al., 2021). Ethical considerations are particularly relevant in STEM education, where AI must facilitate – rather than dictate – scientific inquiry, problem-solving, and innovation. Developing an ethical framework ensures that AI supports equitable, transparent, and practical learning experiences as AI adoption expands. This discussion naturally leads to the next critical aspect: *How can we translate these theoretical insights into practical solutions for educators?*

Practical relevance

Current gaps in STEM education and the need for AI solutions

While AI holds immense potential for transforming STEM education, its real-world impact depends on how effectively it addresses existing challenges. Limited access to AI tools, insufficient collaboration among educators, and ethical concerns create significant gaps that hinder innovation in teaching methodologies and restrict students' opportunities to engage with emerging technologies.

One of the most pressing issues is the digital divide affecting institutions in developing regions and underfunded schools (Mathrani et al., 2022). Many universities and schools lack the financial and technological resources needed to implement AI-driven educational tools, leading to disparities in student learning experiences. Additionally, STEM educators struggle to adopt AI-based teaching methods due to the absence of structured training programmes and accessible AI integration platforms.

Moreover, the fragmented adoption of AI across institutions results in isolated efforts, where only well-funded universities and research centres benefit from AI-driven innovations. Meanwhile, most educators lack the necessary support and infrastructure to implement AI effectively in their classrooms (Michel-Villarreal et al., 2023).

These challenges highlight the urgent need for scalable, AI-powered solutions that seamlessly integrate into existing educational systems. The fundamental question remains: How can AI be leveraged to bridge these gaps and provide tangible benefits for both STEM educators and students?

AI as a solution for scalable and innovative teaching

AI-driven solutions have demonstrated their potential to transform STEM education, offering personalized learning environments, real-time feedback, and interactive digital platforms. These tools have significantly advanced educational methodologies by enabling adaptive instruction, intelligent assessments, and data-driven insights (Dede et al., 2020).

However, for AI to reach its full potential, it must be broadly accessible, supported by structured educator training, and effectively integrated into diverse learning environments. To achieve this, several AI-driven strategies have emerged as practical approaches to addressing key challenges in STEM education, particularly in personalization, assessment, and professional development:

- Personalized Learning through AI-Driven Tools: Adaptive learning is among the most transformative AI applications in education. AI-powered platforms dynamically adjust instructional content based on

student performance and learning needs. Intelligent Tutoring Systems (ITS) provide personalized learning experiences, targeted feedback, and scaffolded support, particularly in STEM disciplines where iterative problem-solving is essential. Platforms like Knewton and Squirrel AI have demonstrated the effectiveness of AI-driven personalization in enhancing engagement and learning outcomes, equipping students with customized educational pathways. However, many educators still struggle to access and implement these strategies, especially in institutions with limited infrastructure or training opportunities. Expanding the availability and support for AI-powered adaptive learning remains a priority.

- AI-Powered Assessments for Real-Time Feedback: Automated assessment systems and AI-driven analytics provide valuable insights into student progress, enabling educators to identify learning gaps, personalize instruction, and optimize teaching strategies. AI-powered platforms such as Edmentum and Century Tech have significantly contributed to streamlining evaluations, providing instant feedback, and supporting data-informed teaching approaches. The increasing adoption of AI-enhanced assessments underscores their effectiveness in supporting student learning and reducing educator workload. However, ensuring these tools are widely accessible and seamlessly integrated into institutional Learning Management Systems (LMS) remains crucial for maximizing their impact. Developing frameworks for scalable AI-powered assessments is essential for inclusive AI adoption in STEM education.
- Virtual AI Sandboxes for Experimentation and Collaboration: One of the biggest challenges in AI adoption is educators' training and confidence in using AI-driven tools. AI-powered virtual sandboxes address this issue by providing controlled environments where educators can explore, experiment with, and refine AI-enhanced teaching strategies before applying them in real classrooms. Initiatives such as AI4EDU and the Open Learning Initiative (OLI) have created structured spaces for educators to engage with AI, promoting professional development and innovation in instructional design. However, access to these platforms is often limited to research initiatives or institutions with advanced AI infrastructures. Expanding the availability of collaborative virtual sandboxes could help more educators develop, test, and refine AI-enhanced teaching methodologies. Providing structured training environments for risk-free experimentation would further facilitate effective AI adoption.

The advancements achieved through adaptive learning platforms, AI-driven assessments, and virtual experimentation spaces highlight AI's transformative potential in STEM education. These solutions have already enhanced student engagement, personalized instruction, and learning

outcomes. However, a significant challenge remains – ensuring that AI-driven methodologies are widely accessible, seamlessly integrated across diverse learning environments, and continuously refined through educator collaboration.

AI-driven community platform for STEM educators

To address the challenges in AI integration, we propose STEM-CARES (STEM Community for AI Resources and Educational Strategies) – an initiative designed to create a scalable, AI-powered ecosystem for STEM educators. This platform would serve as a collaborative hub where educators can access AI-driven teaching strategies, share best practices, and experiment with AI tools before implementing them in their classrooms (see Figure 4.2).

Conceptual Framework and Core Components. The STEM-CARES platform aims to seamlessly integrate AI into STEM education by offering four core components:

- AI-Powered Teaching Repository – A curated database of AI-enhanced teaching methodologies tailored for STEM disciplines. Educators can contribute, review, and refine strategies, ensuring adaptability across diverse learning environments.

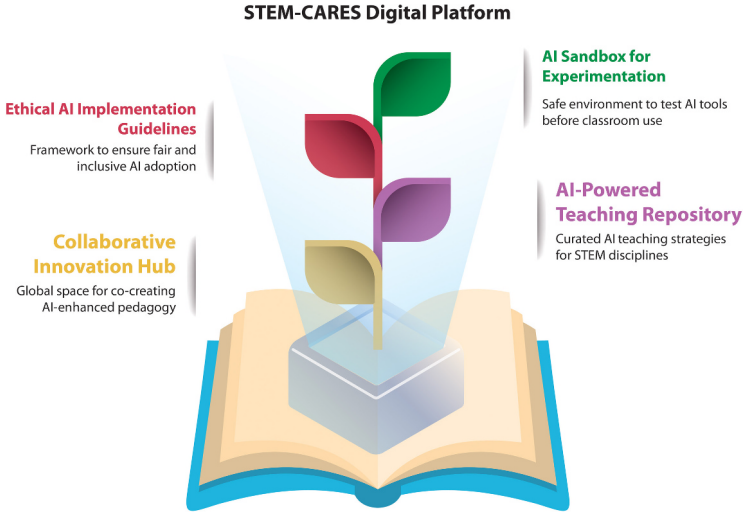

Figure 4.2 AI-driven community platform for STEM educators.

- Collaborative Innovation Hub – A dedicated space for interdisciplinary collaboration, where educators, researchers, and policymakers can exchange knowledge, co-develop AI-based teaching methodologies, and validate their effectiveness.
- AI Sandbox for Experimentation – A virtual environment where educators can test AI-driven tools and methodologies in a controlled setting, allowing for iterative refinement before classroom deployment.
- Ethical AI Implementation Guidelines – A framework to ensure that AI applications align with ethical standards, mitigating potential biases and promoting fairness and inclusivity in AI-driven learning environments.

These components would establish a structured, scalable, and collaborative approach to AI integration, equipping educators with the necessary resources, training, and support to implement AI-driven strategies effectively.

Expected Impact of STEM-CARES. If successfully implemented, STEM-CARES could significantly enhance AI integration in STEM education by:

- Increasing accessibility to AI-powered teaching tools and resources, bridging the gap between well-funded and under-resourced institutions.
- Enhancing collaboration through a global knowledge-sharing network, fostering innovation and interdisciplinary cooperation.
- Facilitating professional development by providing hands-on AI training through the AI Sandbox, equipping educators with the necessary skills for effective AI adoption.
- Ensuring ethical AI adoption, mitigating biases, and promoting inclusivity in AI-enhanced STEM education.

To ensure its effectiveness, pilot programmes, educator feedback loops, and iterative refinements would be continuously conducted, aligning the platform's development with educators' evolving needs.

Vision and objectives

Integrating AI into STEM education offers immense opportunities for innovation, yet significant barriers remain in accessibility, educator training, and ethical implementation. The challenges discussed underscore the urgent need for a structured, scalable, and inclusive approach that enables educators to integrate AI into their teaching practices effectively.

To address these gaps, we envision STEM-CARES (STEM Community for AI Resources and Educational Strategies) as a comprehensive framework designed to support educators, foster collaboration, and promote the responsible integration of AI in STEM education.

Bridging the gap between AI and teaching excellence

This initiative aims to close the divide between AI advancements and their practical application in teaching methodologies. While AI offers dynamic, data-driven approaches to instruction, many educators lack the tools, resources, and structured guidance to integrate these technologies into their classrooms successfully.

STEM-CARES seeks to bridge this gap by creating an open, collaborative, and educator-centred platform where AI-enhanced teaching strategies can be developed, shared, and refined. The platform would:

- Empower educators with AI-driven tools tailored explicitly for STEM disciplines.
- Promote interdisciplinary collaboration, enabling educators to co-develop and validate AI-based methodologies.
- Ensure inclusivity and ethical AI adoption, addressing concerns related to algorithmic bias and equitable access to AI-enhanced learning.

By aligning AI integration with pedagogical best practices, STEM-CARES enables educators to harness AI's potential while maintaining student-centred learning experiences, emphasizing engagement, critical thinking, and equity.

Specific goals of the project

To bring this vision to life, STEM-CARES is structured around four key objectives:

1 *Providing educators with ready-to-implement, AI-enhanced strategies for STEM disciplines*. STEM-CARES will be a centralized repository of curated AI-driven teaching methodologies, ensuring adaptability across diverse educational settings. This resource will equip educators with practical AI tools to enhance personalized instruction and student engagement.
2 *Promoting peer collaboration and knowledge-sharing to drive innovative teaching methods*. The platform will establish a global network where educators can exchange ideas, share AI-driven pedagogical approaches, and engage in continuous professional development. By fostering a community-driven knowledge-sharing model, STEM-CARES ensures that educators receive the support needed to integrate AI effectively into their teaching practices. The platform would establish a collaborative network where educators could exchange ideas, share AI-driven pedagogical approaches, and participate in continuous professional development. Integrating community-driven knowledge-sharing, STEM-CARES would ensure educators have the necessary support to implement AI effectively in their classrooms.

3 *Developing an ethical framework to ensure inclusive, bias-resistant AI applications*. Addressing concerns around algorithmic bias and accessibility disparities is critical for ethical AI adoption. STEM-CARES will incorporate guidelines to help educators evaluate AI tools, ensuring that AI educational applications promote fairness, transparency, and inclusivity.
4 *Supporting scalable solutions to enhance student engagement, retention, and learning outcomes*. STEM-CARES will focus on scalability, allowing AI-enhanced teaching strategies to be seamlessly integrated into Learning Management Systems (LMS) and other digital educational platforms. This approach will facilitate broad adoption, ensuring that students from diverse backgrounds benefit from AI-driven learning experiences.

Connecting STEM-CARES to global education goals

The objectives of STEM-CARES align directly with the United Nations Sustainable Development Goals (SDGs), particularly:

- SDG 4 – Quality Education: Ensuring inclusive, equitable, and high-quality education by making AI-enhanced learning resources widely accessible.
- SDG 9 – Industry, Innovation, and Infrastructure: Driving innovation in education by integrating AI into STEM instruction and fostering interdisciplinary collaboration.

By embedding AI-driven strategies into STEM education, STEM-CARES will advance educational equality, foster technological innovation, and prepare students for AI-integrated career landscapes.

Sum of experiences and capacities

Our team comprises a diverse and dynamic group of scholars and researchers united by a shared commitment to advancing educational innovation through interdisciplinary collaboration and the integration of artificial intelligence (AI) in STEM education. Collectively, we bring together expertise across STEM education, engineering, materials science, educational systems, AI applications, and gender studies, reflecting a rich blend of academic and practical experience spanning multiple continents.

Our expertise is rooted in extensive research and leadership roles within globally recognized institutions, including the Institute for the Future of Education at Tecnológico de Monterrey, Politecnico di Torino (Italy), Juraj Dobrila University of Pula (Croatia), Kaunas University of Technology (Lithuania), and the University of Twente (Netherlands). This international composition allows us to leverage diverse educational

systems, methodologies, and cultural perspectives, enriching our approach to STEM education reform and AI-driven pedagogical strategies.

We are actively engaged in global academic networks, contributing to associations such as ACM, IEEE, EUNIS ELTF, and ISWE, as well as educational innovation organizations like ICTMA, ASEE, PME-NA, and REDIIEN. Our commitment to fostering talent and diversity in STEM fields is demonstrated through participation in mentorship programmes, such as 1000Girls-1000Futures, Mentor in Science (British Council), and the Academic Women in STEM Mentoring Program.

Our multidisciplinary strengths lie at the intersection of developing AI-powered educational technologies, advancing STEM teacher development, and pioneering research in gender equality and interdisciplinary learning models. Our academic impact is reflected in high h-index scores, numerous peer-reviewed publications, and leadership in international research projects such as Erasmus+, Horizon Europe, and TEMPUS. Additionally, our team members hold advisory roles in educational policy, actively shaping the future of STEM education through evidence-based practices.

Together, we form a synergistic force capable of addressing complex educational challenges through cutting-edge research, technological innovation, and inclusive practices. Beyond academic excellence, we are educators, innovators, and advocates, committed to transforming STEM education globally through the ethical and practical application of AI.

Expected impact of the project

Long-term vision for AI in STEM education

Artificial intelligence is transforming education by offering personalized learning experiences, data-driven insights, and enhanced instructional methodologies. However, as discussed, accessibility barriers, insufficient educator training, and ethical concerns remain significant obstacles to widespread adoption.

STEM-CARES provides a comprehensive and scalable solution to integrate AI into STEM education in a responsible manner. By empowering educators with AI-driven teaching strategies, fostering interdisciplinary collaboration, and ensuring ethical AI adoption, this initiative has the potential to:

- Improve teaching quality by equipping educators with adaptable, AI-enhanced instructional methods.
- Enhance student learning outcomes through personalized, interactive, and data-driven approaches.

- Promote equity in STEM education by making AI resources accessible across diverse learning environments.
- Strengthen AI literacy among educators, ensuring they have the competencies to implement AI effectively.

By addressing both practical and ethical considerations, STEM-CARES could serve as a model for responsible AI adoption, demonstrating how AI can bridge rather than widen educational disparities.

The future of education: Accessibility, inclusion, quality, and openness

The core principles of STEM-CARES focus on building an AI-enhanced educational ecosystem that is accessible, inclusive, high-quality, and open:

- Accessibility: AI-driven resources should be available to all educators and students, regardless of their institution's infrastructure or funding. STEM-CARES reduces barriers to AI adoption by providing scalable, adaptable, and cost-effective solutions.
- Inclusion: Ensuring AI promotes equity and diversity in STEM education is essential. The platform will incorporate ethical guidelines to prevent bias, foster culturally responsive AI-driven strategies, and support underrepresented communities.
- High Quality: By integrating data-driven insights, evidence-based methodologies, and real-time educator feedback, STEM-CARES will serve as a dynamic knowledge hub, ensuring that AI-based teaching approaches continuously evolve to meet the highest educational standards.
- Openness: A key feature of STEM-CARES is open-source collaboration, allowing educators, researchers, and institutions to contribute, refine, and freely access AI-driven teaching strategies, fostering a culture of shared innovation.

Through this vision, STEM-CARES aims to transform global STEM education, ensuring AI enhances learning experiences while remaining ethical, inclusive, and widely accessible.

Enhanced teaching quality and student outcomes

AI-driven pedagogical strategies have demonstrated their ability to improve teaching effectiveness, student engagement, and learning outcomes. By equipping educators with evidence-based AI methodologies, STEM-CARES could:

- Improve student retention and graduation rates in STEM disciplines through personalized learning pathways and adaptive assessments.

- Increase student interest in STEM careers, particularly among underrepresented groups, by making AI-enhanced learning more engaging and accessible.

These advancements would broaden participation in STEM fields and contribute to the diversification of the global STEM workforce.

Professional growth for educators

STEM-CARES supports continuous professional development, ensuring that educators stay at the forefront of AI-driven pedagogical advancements. Through interactive learning modules, peer collaboration, and AI experimentation environments, educators will be able to:

- Enhance their teaching competencies in AI-enabled classrooms, gaining confidence in leveraging AI for instruction.
- Engage in lifelong learning within a peer-driven ecosystem, exchanging insights, refining AI strategies, and participating in professional development activities.

By prioritizing educator empowerment, STEM-CARES will establish a sustainable, community-driven framework for AI literacy and professional growth.

Innovation and scalability

One of the core strengths of STEM-CARES is its potential for scalability and interdisciplinary expansion:

- Dynamic Repository of AI Strategies – The platform's curated database of AI-driven methodologies can serve as a scalable model, extending beyond STEM disciplines.
- Broad Applicability – AI-enhanced teaching approaches can be adapted for higher education, vocational training, and K-12 STEM programmes.
- Long-Term Relevance – By maintaining a flexible, evolving repository of AI-driven educational strategies, STEM-CARES will ensure AI remains a sustainable and continuously improving resource for educators.

This scalability will enable STEM-CARES to adapt to emerging technological trends while maintaining a strong focus on educational innovation and equality.

Data-driven policy and EdTech development

Insights derived from platform usage, educator contributions, and AI strategy outcomes could inform educational policies and EdTech innovations, aligning with institutional and societal goals. The data collected through STEM-CARES could:

- Support policy development by providing evidence-based recommendations for AI literacy programmes in education.
- Guide future EdTech advancements, ensuring that AI tools align with pedagogical best practices and real-world teaching needs.
- Facilitate cross-sector collaboration, enabling researchers, policymakers, and technology developers to co-create AI solutions that address educational challenges.

By bridging educational practice with policy and technology development, STEM-CARES could contribute to the long-term transformation of AI integration in global education systems.

Call to action

Integrating AI into STEM education requires a collective effort to bridge the gap between technology, pedagogy, and policy. STEM-CARES is more than just a platform – it aims to become a dynamic ecosystem that supports educators, fosters collaboration, and drives AI-enhanced education. If implemented, STEM-CARES could:

- Provide access to a curated repository of AI-driven teaching strategies, enabling educators to adopt innovative methodologies tailored to diverse STEM disciplines.
- Create collaborative spaces for educators and researchers to co-develop and share best practices, case studies, and AI-enhanced instructional designs.
- Offer professional development opportunities, equipping educators with the necessary skills to integrate AI through workshops, peer learning, and continuous training modules.
- Ensure ethical AI adoption, supporting the responsible use of AI in education by addressing bias, inclusivity, and data privacy issues.
- Generate insights for policy and EdTech development, leveraging data-driven outcomes to inform educational strategies and contribute to the evolution of AI applications in teaching and learning.

We envision STEM-CARES as a catalyst for change, fostering an environment where AI is not just a tool but a transformative force that enhances equity, accessibility, and quality in STEM education (see Figure 4.3).

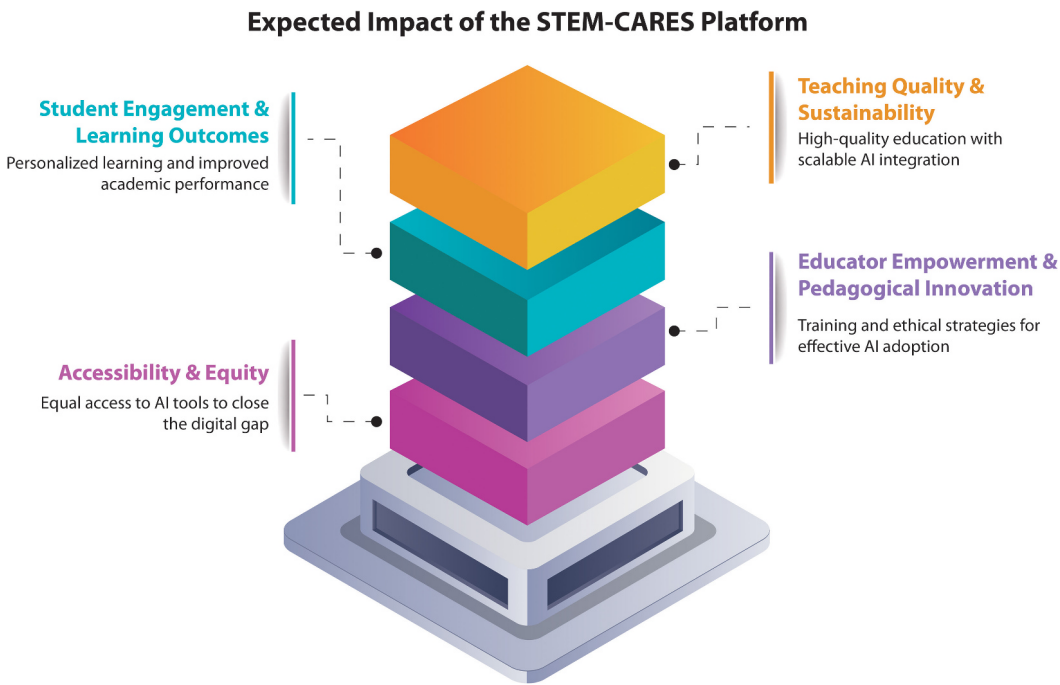

Figure 4.3 Expected impact of the STEM-CARES digital platform on teaching, learning, and educational equality.

Bringing together educators, institutions, researchers, and policymakers, STEM-CARES could lay the foundation for a future-ready educational ecosystem where AI empowers teachers and learners to thrive.

Integrative summary

A Manifesto for "STEM-CARES: STEM Community for AI Resources and Educational Strategies"

Who Are We? We are an interdisciplinary and international collective of educators and researchers, united by a shared commitment to transforming STEM education through the ethical and practical integration of artificial intelligence (AI). Our expertise spans STEM education, engineering, materials science, AI applications, educational systems, and gender studies, enabling us to develop inclusive, high-quality educational practices. Representing leading institutions such as the Institute for the Future of Education at Tecnológico de Monterrey, Politecnico di Torino (Italy), Juraj Dobrila University of Pula (Croatia), Kaunas University of Technology (Lithuania), and the University of Twente (Netherlands), we leverage global perspectives and networks to drive innovation in STEM learning environments. Our vision is rooted in interdisciplinary collaboration, educational equity, and sustainable innovation, ensuring that AI enhances, rather than replaces, human-centred learning in alignment with open science values.

- ***What Do We Want?*** We aim to bridge the gap between advancements in artificial intelligence and practical, impactful STEM education by developing STEM-CARES (STEM Community for AI Resources and Educational Strategies), an open-access platform designed to empower educators, foster collaboration, and promote ethical AI integration in STEM disciplines. This initiative addresses key challenges such as limited AI literacy, inequitable access to educational resources, and the lack of collaborative knowledge-sharing spaces. Through STEM-CARES, educators will gain access to AI-driven teaching strategies tailored to STEM disciplines, enabling them to adopt, refine, and implement AI-enhanced pedagogies effectively. The platform will foster peer collaboration, creating a global network where educators, researchers, and policymakers can exchange insights, co-develop methodologies, and share best practices. Beyond

advancing pedagogy, STEM-CARES is committed to ensuring that AI in education is implemented ethically and inclusively, mitigating biases and addressing concerns about equitable access to technology. STEM-CARES seeks to enhance teaching quality, improve student engagement, and contribute to lifelong learning in STEM fields by developing evidence-based methodologies and providing ongoing professional development opportunities. This initiative envisions a future where AI catalyses innovation, breaking down barriers to quality STEM education and empowering educators to create more dynamic, inclusive, and effective learning environments rooted in open science collaboration.

- ***How Will This Project Contribute to Open Education, Science, and Knowledge?*** STEM-CARES is designed to drive open education, open science, and knowledge-sharing, ensuring that AI's benefits are accessible to all educators, regardless of geographic or institutional constraints. The platform will serve as a hub for co-creation, collaboration, and knowledge exchange among educators, researchers, and policymakers worldwide by providing a centralized, open-access repository of AI-enhanced teaching strategies. This initiative is grounded in transparency, inclusivity, and ethical AI implementation. By integrating ethical frameworks that prioritize fairness and diversity, STEM-CARES will contribute to the responsible use of AI in education, ensuring that technology is leveraged to narrow educational gaps rather than widen them. The platform will generate data-driven insights, offering evidence-based recommendations for AI adoption in education policy and EdTech development. These insights will help institutions and decision-makers align AI applications with pedagogical best practices and real-world teaching needs, supporting continuous innovation in AI-driven learning. Through STEM-CARES, we seek to foster a global community dedicated to the ethical and impactful use of AI in STEM education. This initiative will not only expand access to cutting-edge educational tools; it will also contribute to sustainable advancements in teaching and learning, reinforcing the principles of open science, collaboration, and social responsibility in education (see Figure 4.4).

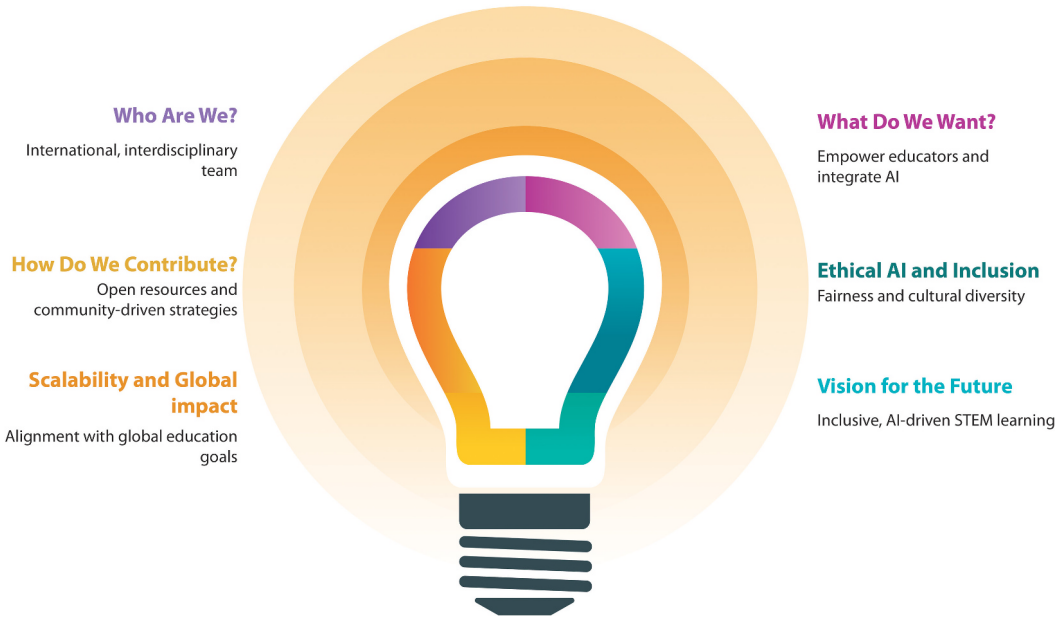

Figure 4.4 Integrative summary for the manifesto "STEM-CARES: STEM Community for AI Resources and Educational Strategies"

References

Adeshola, I., & Adepoju, A. P. (2024). The opportunities and challenges of ChatGPT in education. *Interactive Learning Environments*, *32*(10), 6159–6172. https://doi.org/10.1080/10494820.2023.2253858

Ahuja, N. J., Dutt, S., Choudhary, S. L., & Kumar, M. (2022). Intelligent tutoring system in education for disabled learners using human–computer interaction and augmented reality. *International Journal of Human–Computer Interaction*, 1–13. https://doi.org/10.1080/10447318.2022.2124359

Al-Zahrani, A. M., & Alasmari, T. M. (2025). A comprehensive analysis of AI adoption, implementation strategies, and challenges in higher education across the Middle East and North Africa (MENA) region. *Education and Information Technologies*, 1–51. https://doi.org/10.1007/s10639-024-13300-y

Astuti, N. H., Rusilowati, A., & Subali, B. (2021). STEM-based learning analysis to improve students' problem solving abilities in science subject: A literature review. *Journal of Innovative Science Education*, *10*(1), 79–86. https://doi.org/10.15294/jise.v9i2.38505

Azevedo, F., Liu, M., Pennington, C. R., Pownall, M., Evans, T. R., Parsons, S., Elsherif, M. M., Micheli, L., Westwood, S., & FORRT. (2021). Towards a culture of open scholarship: The role of pedagogical communities. *BMC Research Notes*, *15*(1), 1–5. https://doi.org/10.1186/s13104-022-05944-1

Berge, O. K., & Haugsevje, Å. D. (2024). Present absence: When cultural participation goes digital. *International Journal of Cultural Policy*, 1–13. https://doi.org/10.1080/10286632.2024.2433484

Bulathwela, S., Pérez-Ortiz, M., Holloway, C., Cukurova, M., & Shawe-Taylor, J. (2024). Artificial intelligence alone will not democratise education: On educational inequality, techno-solutionism and inclusive tools. *Sustainability*, *16*(2), 781. https://doi.org/10.3390/su16020781

Chan, C. K. Y., & Tsi, L. H. Y. (2024). Will generative AI replace teachers in higher education? A study of teacher and student perceptions. *Studies in Educational Evaluation*, *83*, 101395. https://doi.org/10.1016/j.stueduc.2024.101395

Chandel, P., & Lim, F. V. (2024). Generative AI and literacy development in the language classroom: A systematic review of literature. *Ubiquitous Learning*, *18*(2), 31–49. https://doi.org/10.18848/1835-9795/CGP/v18i02/31-49

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

Čubela, D., Rossner, A., & Neis, P. (2023). Using problem-based learning and gamification as a catalyst for student engagement in data-driven engineering education: A report. *Education Sciences*, *13*(12), 1223. https://doi.org/10.3390/educsci13121223

Dede, C., & Richards, J. (2020). *The 60-year curriculum: New models for lifelong learning in the digital economy*. Routledge. https://doi.org/10.4324/9781003013617

Delello, J. A., Sung, W., Mokhtari, K., Hebert, J., Bronson, A., & De Giuseppe, T. (2025). AI in the classroom: Insights from educators on usage, challenges, and mental health. *Education Sciences*, *15*(2), 113. https://doi.org/10.3390/educsci15020113

Gligorea, I., Cioca, M., Oancea, R., Gorski, A.-T., Gorski, H., & Tudorache, P. (2023). Adaptive learning using artificial intelligence in e-learning: A literature review. *Education Sciences*, *13*(12), 1216. https://doi.org/10.3390/educsci13121216

Holmes, W., Bialik, M., & Fadel, C. (2021). *Artificial intelligence in education: Promises and implications for teaching and learning*. Centre for Curriculum Redesign.

Khan, M. S., Umer, H., & Faruqe, F. (2024). Artificial intelligence for low income countries. *Humanities and Social Sciences Communications*, *11*(1), 1–13. https://doi.org/10.1057/s41599-024-03947-w

Klimova, B., Pikhart, M., & Kacetl, J. (2023). Ethical issues of the use of AI-driven mobile apps for education. *Frontiers in Public Health*, *10*, 1118116. https://doi.org/10.3389/fpubh.2022.1118116

Luckin, R., & Cukurova, M. (2019). Designing educational technologies in the age of AI: A learning sciences-driven approach. *British Journal of Educational Technology*, *50*(6), 2824–2838. https://doi.org/10.1111/bjet.12861

Mathrani, A., Sarvesh, T., & Umer, R. (2022). Digital divide framework: Online learning in developing countries during the COVID-19 lockdown. *Globalisation, Societies and Education*, *20*(5), 625–640. https://doi.org/10.1080/14767724.2021.1981253

Miao, F., Holmes, W., Huang, R., & Zhang, H. (2021). *AI and education: A guidance for policymakers*. Unesco Publishing.

Michel-Villarreal, R., Vilalta-Perdomo, E., Salinas-Navarro, D. E., Thierry-Aguilera, R., & Gerardou, F. S. (2023). Challenges and opportunities of generative AI for higher education as explained by ChatGPT. *Education Sciences*, *13*(9), 856. https://doi.org/10.3390/educsci13090856

Parsons, S., Azevedo, F., Elsherif, M. M., Guay, S., Shahim, O. N., Govaart, G. H., Norris, E., O'Mahony, A., Parker, A. J., Todorovic, A., Pennington, C. R., Garcia-Pelegrin, E., Lazić, A., Robertson, O. M., Middleton, S. L., Valentini, B., McCuaig, J., Baker, B. J., Collins, E., & Aczel, B. (2022). A community-sourced glossary of open scholarship terms. *Nature Human Behaviour*, *6*(3), 312–318. https://doi.org/10.1038/s41562-021-01269-4

Raman, R., Lathabhai, H., Pattnaik, D., Kumar, C., & Nedungadi, P. (2024). Research contribution of bibliometric studies related to sustainable development goals and sustainability. *Discover Sustainability*, *5*(1), 7. https://doi.org/10.1007/s43621-024-00182-w

Sghir, N., Adadi, A., & Lahmer, M. (2023). Recent advances in predictive learning analytics: A decade systematic review (2012–2022). *Education and Information Technologies*, *28*, 8299–8333. https://doi.org/10.1007/s10639-022-11536-0

Sperling, K., Stenberg, C. J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. *Computers and Education Open*, *100169*. https://doi.org/10.1016/j.caeo.2024.100169

Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G., & Vasileva, T. (2024). AI-driven adaptive learning for sustainable educational transformation. *Sustainable Development*, *33*(2), 1921–1947. https://doi.org/10.1002/sd.3221

Uzumcu, O., & Acilmis, H. (2024). Do innovative teachers use AI-powered tools more interactively? A study in the context of diffusion of innovation theory. *Technology, Knowledge and Learning*, *29*(2), 1109–1128. https://doi.org/10.1007/s10758-023-09687-1

Williamson, B., & Eynon, R. (2020). Historical threads, missing links, and future directions in AI in education. *Learning, Media and Technology*, *45*(3), 223–235. https://doi.org/10.1080/17439884.2020.1798995

Xia, Y., Shin, S.-Y., & Kim, J.-C. (2024). Cross-cultural intelligent language learning system (CILS): Leveraging AI to facilitate language learning strategies in cross-cultural communication. *Applied Sciences*, *14*(13), 5651. https://doi.org/10.3390/app14135651

Yan, L., Greiff, S., Teuber, Z., & Gašević, D. (2024). Promises and challenges of generative artificial intelligence for human learning. *Nature Human Behaviour*, *8*(10), 1839–1850. https://doi.org/10.1038/s41562-024-02004-5

Yang, Y., Sun, W., Sun, D., & Salas-Pilco, S. Z. (2024). Navigating the AI-enhanced STEM education landscape: A decade of insights, trends, and opportunities. *Research in Science & Technological Education*, 1–25. https://doi.org/10.1080/02635143.2024.2370764

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 1–27. https://doi.org/10.1186/s41239-019-0171-0

Zeller, F., & Dwyer, L. (2022). Systems of collaboration: Challenges and solutions for interdisciplinary research in AI and social robotics. *Discover Artificial Intelligence*, *2*(1), 12. https://doi.org/10.1007/s44163-022-00027-3