AI and Robotics in Education

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Abstract

Artificial Intelligence is one of the greatest challenges for education, driving the exploration of emerging trends in this field. AI helps in the development of adaptive learning systems, personalised assistance and the automation of teaching tasks, with potential impacts on transforming the role of educators and evolving traditional educational methodologies. The rapid technological advancement has transformed the way work, communication and learning are carried out and it is recognised that Artificial Intelligence (AI) plays a key role in this transformation. Digitalisation evolution has brought with it an unprecedented surge in the evolution of digital technologies, with AI and educational robotics standing out as the two fundamental pillars of innovation in education. AI enables the development of systems capable of analysing large volumes of data, facilitating personalised, automated processes, and improving educational management (Owoc et al., 2021). Educational robotics has introduced physical tools that enrich classroom interaction, promoting the development of technical, cognitive, and socio-emotional skills in students (Müller & Koltun, 2021).These technologies are changing the way students learn and teachers teach. However, with the rapid adoption of AI and robotics, significant challenges arise related to data privacy, equity of access, and the sustainability of their implementation in different educational contexts. Therefore, it is necessary for the analysis of the use of these technologies to go beyond their technological applications and also focus on the ethical, social, and pedagogical aspects that accompany their integration into educational systems (García-Peñalvo, 2024).

This study aims to explore the historical evolution of AI and robotics in education, their current applications, and how these technologies are changing classroom teaching and learning.

Keywords: Artificial intelligence, Education, Robotics, Educational Methodologies

Introduction
Artificial Intelligence (AI) is the ability of a digital computer or computer-controlled robot to imitate intelligent human behaviour. The tasks it can perform require the ability to reason, discern, discover meaning, and learn from past experience. AI is taught to learn from data and adapt by developers. It can function to solve problems, answer questions, make predictions, and even offer strategy.
Some AI matches human abilities for specific tasks, and others work faster or more efficiently than humans can. From your phone to your car, smart TVs to kitchen appliances, and countless areas in between, AI is involved in much of what we do. However, no existing AI can perform the same extensive range of tasks that humans can.

History of AI
While the AI debate may seem recent to many of us, AI has actually been around for decades. In ancient times, inventors made things called "automatons" which were mechanical and moved independently of human intervention. The word "automaton" comes from ancient Greek, and means "acting of one's own will." One of the earliest records of an automaton comes from 400 BCE and refers to a mechanical pigeon created by a friend of the philosopher Plato. Many years later, one of the most famous automatons was created by Leonardo da Vinci around the year 1495.
British logician and computer pioneer Alan Turing began exploring machine intelligence in the 1930s. In the 1950s, he questioned whether a machine can think and introduced the central concepts of AI. From calculators to cell phones, the introduction of AI and its potential impact on education and learning is often hotly debated, spurring conversations

around both potential and risks. No matter where you stand, understanding the basics and adapting to ever-evolving tech is critical for both you and your students.

In subsequent decades, technology continued to advance globally, making its way into the classroom. With each new tool came unparalleled possibilities—if the tech was implemented right. More recently, the internet and smartphones have permanently altered the educational environment. AI is on track to do the same.

The Evolution of Educational Robotics: Past, Present, and Future

Educational robotics has revolutionised how students interact with technology, develop problem-solving skills, and engage in STEM education. Over time, robotics in schools and Colleges has evolved from simple tools to a dynamic and impactful learning platform, equipping students with the skills they need for the future.

The Past: The History of Robotics in Education

The history of robotics in education can be traced back to the 1960s, when the idea of using robots as learning aids began to take shape. One of the early milestones in **educational robotics** came in the 1970s with **Seymour Papert's** creation of the **LOGO** programming language and the **Turtle Robot**. These innovations allowed children to program simple commands, helping them grasp the fundamentals of computational thinking and problem-solving in a hands-on way.

The late 1990s saw the introduction of **LEGO Mindstorms**, which revolutionized robotics in schools. The LEGO Mindstorms kits merged play with learning, giving students the ability to build and program robots, bringing abstract STEM concepts to life. This period marked a significant leap in the accessibility of robotics education, making it more widespread and user-friendly.

The Present: Robotics in Schools Today

Fast forward to the present, and **robotics in schools** is more than just a supplementary learning tool—it has become a central component of STEM curricula worldwide. Educational robotics kits like **VEX Robotics**, **LEGO Mindstorms** EV3, and **Arduino** allow students to build, code, and experiment with robots, fostering creativity and innovation.

The rise of block-based coding platforms such as **Programing Scratch** and **Blockly** has made learning robotics more accessible for younger students. Programs like those offered by **Little Inventors** incorporate these tools to teach kids aged 6-14 how to code and build robots, helping them develop critical thinking and technical skills in a fun, engaging environment.

Educational robotics has also become a competitive endeavor. Events like the **World Robot Olympiad (WRO)** and **FIRST Robotics** motivate students to apply their knowledge in real-world challenges, fostering teamwork, innovation, and resilience. This hands-on learning approach has turned robotics into a vibrant and dynamic part of modern education.

Educational robotics has also evolved into a competitive arena. Prestigious events like the World Robot Olympiad (WRO) and FIRST Lego League Robotics Competition challenge students to apply their knowledge in real-world scenarios, inspiring teamwork, innovation, and problem-solving. These hands-on experiences have made robotics an integral and dynamic part of today's education system.

The Future: Robotics Education in the Years to Come

The future of **robotics education** holds exciting possibilities. As **artificial intelligence (AI)**, **machine learning**, and autonomous systems become more integrated into robotics, the educational tools available to students will become even more sophisticated. In the near future, we could see robots in schools and Colleges that adapt to individual learning styles, offering personalized instruction and interactive experiences that make learning more engaging and tailored.

Furthermore, robotics in education will likely expand beyond traditional STEM subjects. Robots are already being used to teach art, languages, and even social skills. This interdisciplinary approach will continue to grow, making robotics a versatile tool that supports a wide range of educational goals.

Current Applications of AI and Robotics in Education

The integration of Artificial Intelligence (AI) and Robotics is profoundly reshaping pedagogical approaches and learning experiences within the context of current educational trends. These technologies offer transformative opportunities for personalised learning, enhanced student engagement, and significant administrative efficiencies, while also presenting complex challenges that demand careful consideration and strategic solutions.

Real-World Applications of Robotics in Education

1. Robotics in Engineering & Automation

One of the most obvious applications of Robotics Education is in engineering and automation. The world is rapidly moving toward automation, with industries from manufacturing to healthcare relying on robots for efficiency. By introducing robotics in schools, we're preparing students for high-demand careers in engineering, automation, and artificial intelligence.

2. Healthcare: AI-Powered Medical Assistance

Believe it or not, robotics and AI are already playing a crucial role in healthcare. From robotic-assisted surgeries to AI-driven diagnosis tools, the medical field is seeing rapid advancements.

How does this relate to students?

- **Medical students** are using AI-powered simulations to practice surgeries before working with real patients.
- **AI-driven robots** help analyse complex medical data, improving diagnosis and treatment plans.
- **Exoskeletons and robotic prosthetics** are changing lives, allowing people with disabilities to move independently.

3. Robotics in Agriculture: Feeding the Future

With the global population growing, food production must become more efficient and sustainable. That's where robotics and AI-driven automation come in.

- **Autonomous tractors and drones** help farmers monitor crop health and optimise irrigation.
- **AI-powered sensors** analyse soil quality, predicting the best conditions for planting.
- **Automated harvesting robots** reduce food wastage and increase efficiency.

5. Smart Cities: AI in Urban Development

Imagine living in a city where traffic lights adjust automatically to reduce congestion, smart waste bins alert authorities when they need emptying, and AI-driven security systems ensure safety.

That's not science fiction—it's happening right now with the help of AI and robotics.

- AI-driven traffic control improves road safety and reduces fuel wastage.
- Autonomous delivery robots and drones are changing the way we receive goods.
- Smart homes use AI assistants like Alexa and Google Assistant to automate daily tasks.

As students learn about robotics and AI, they can contribute to designing and building smarter, more efficient cities. This knowledge can lead to careers in urban planning, AI development, and sustainable infrastructure.

What's Next?

- **AI-Powered Virtual Classrooms** – Personalised AI tutors that adapt to individual learning styles.
- **Autonomous Learning Labs** – Classrooms where students explore and experiment at their own pace.
- **Emotionally Intelligent AI** – Future AI systems may recognise human emotions and adjust teaching methods accordingly.

How does AI personalise learning?

AI personalises learning by creating highly tailored and adaptive educational experiences for individual students:

• **Data Analysis**: AI algorithms meticulously analyse vast datasets, including student responses, pace, errors, engagement patterns, and expressed preferences in real-time.

• **Dynamic Adjustment**: Based on this analysis, AI-driven platforms dynamically adjust content difficulty, instructional methods, pacing, and suggest resources to create unique learning paths. This moves away from a "one-size-fits-all" approach to truly individualised instruction.

• **Intelligent Tutoring Systems (ITS)**: Systems like Carnegie Learning's MATHiaU, DreamBox, Duolingo, Khanmigo, and Squirrel AI provide one-on-one, adaptive instruction and real-time feedback, effectively mimicking human tutors. They diagnose knowledge gaps, offer targeted explanations, and allow students to progress at their own speed.

• **Enhanced Relevance**: AI can tailor learning content to specific student interests, such as customizing math problems for athletes or musicians, which increases relevance and engagement**.**

• **Accelerated Progress**: Research suggests that students in personalized learning environments can progress significantly faster, with some studies indicating a 30-40% improvement in learning speed compared to traditional classrooms. This approach democratizes access to high-quality, individualized support that was traditionally scarce and expensive.

What challenges hinder AI's adoption in education?

The integration of AI into pedagogy faces several significant challenges, encompassing economic, technical, ethical, and human-centric concerns:

• **High Implementation Costs and Digital Divide**: AI systems require substantial initial investment for hardware (e.g., humanoid robots costing around $13,553 USD per unit), specialised infrastructure, technical training, software licenses, and ongoing maintenance. These high costs, along with unequal access to reliable internet and devices, **exacerbate the "digital divide"**, particularly in rural, economically disadvantaged, and developing areas.

• **Teacher Training and Support**: Many educators lack the necessary training, confidence, and ongoing professional development to effectively and ethically integrate AI technologies into their teaching practices. Poorly implemented technology can also add to teacher workload and stress.

Ethical Concerns while using AI in classrooms

The integration of AI in classrooms brings forth several critical ethical considerations that require thoughtful and proactive management:

◦ **Data Privacy and Security**: AI systems necessitate the collection of extensive and sensitive student data (personal information, academic records, behavioural patterns), raising concerns about privacy breaches and misuse. Robust data protection measures and transparent policies are critically needed.

◦ **Algorithmic Bias**: AI algorithms are not neutral and can perpetuate or amplify existing societal biases if trained on skewed or unrepresentative datasets. This can lead to discriminatory outcomes in areas like grading, admissions, or resource allocation, for example, misclassifying writing from non-native English speakers as AI-generated.

◦ **Lack of Transparency and Accountability**: It can be difficult to understand how AI systems arrive at their conclusions or recommendations, impacting trust and accountability.

◦ **Dehumanization Risks and Impact on Human Interaction**: Concerns exist about a potential reduction in essential human interaction within the classroom, which could negatively affect students' social-emotional development and critical thinking. AI inherently lacks the empathy, nuanced understanding, and personal connection that human educators uniquely offer.

◦ **Over-Reliance and De-Skilling**: There is a risk that excessive dependence on AI may erode students' critical thinking, problem-solving, and independent analysis skills. There is a negative correlation between high confidence in AI use and lower critical thinking scores, with AI-generated essays sometimes lacking original thought and exhibiting lower brain engagement.

◦ **Academic Misconduct**: The ease with which AI can generate content raises concerns about **cheating and plagiarism**.

• **Technical and Operational Limitations**: Current AI systems (Artificial Narrow Intelligence) have limitations in handling complex, contextual, and unexpected pedagogical situations, necessitating human oversight.

• **Pedagogical Soundness**: Not all AI tools are built on sound learning science, and their effectiveness varies, with AI-generated content potentially being inaccurate or biased.

• **Acceptance and Adoption Resistance**: Educators may show resistance due to job security concerns, scepticism, or perceived complexity. Cultural and social barriers also exist regarding the replacement of human instructors.

• **Curriculum Misalignment**: AI-generated content may not align with local curricula or cultural contexts.

How do robots foster STEM skills?

Educational robotics is a powerful tool for fostering STEM (Science, Technology, Engineering, and Mathematics) skills through hands-on, engaging, and practical learning experiences:

• **Project-Based and Experiential Learning**: Robotics is extensively used in K–16 STEM education through **project-based learning (PBL) and experiential approaches**. Students actively engage in designing, programming, and manipulating robots, making learning tangible.

• **Computational Thinking (CT) Development**: It is highly promising for cultivating computational thinking skills—the mental process of solving problems using concepts fundamental to computer science—especially among young learners (pre-kindergarten to sixth grade). Specific CT skills developed include Sequencing, Conditionals, Loops, Debugging, and Algorithmic Thinking.

• **Hands-on Coding Experiences**: Educational robots serve as dynamic manipulatives that provide immediate feedback, transforming abstract coding concepts into interactive experiences. Students build, experiment, and program robots, directly engaging with fundamental scientific principles like sensor input, feedback loops, and logical sequencing.

• **Problem-Solving and Critical Thinking**: Robotics fosters essential skills such as problem-solving, design thinking, creativity, and critical thinking**.** The iterative cycle of hypothesis formation, testing, and revision, driven by the direct cause-and-effect relationship between code and robot movement, is crucial for deep conceptual understanding.

• **Skill Development**: Supports 21st-century skills like coding, engineering, and digital fluency**.**

• **Tangible Application**: It makes abstract concepts concrete, leading to deeper internalization of knowledge and a more robust foundation in STEM literacy, which is crucial for future technological careers.

AI plays a crucial role in enhancing inclusivity and providing specialized support for students with diverse learning needs, including those with learning difficulties or disabilities:

• **Adaptive Systems and Personalized Pacing**: AI-driven platforms can adapt content and pacing to individual student needs, including those requiring additional support or with special needs, thereby promoting personalized learning.

• **Assistive Technologies**: AI tools offer features like speech-to-text, text-to-speech, and real-time translation, making previously inaccessible material available to a wider range of learners and promoting inclusivity for multilingual learners and students with disabilities.

• **Early Detection and Intervention**: AI analyses student data (e.g., grades, attendance, engagement patterns) to identify early warning signs of disengagement, dropout risk, or specific learning difficulties. Specialized AI tools, such as Dysolve, can detect dyslexia and other learning disabilities early by analyzing reading patterns and errors, enabling timely tailored support and interventions. For instance, Kentucky utilizes an AI Early Warning Tool to identify at-risk students.

• **Social Robots for Special Needs**: Social robots like NAO and Milo are specifically designed to assist children with Autism Spectrum Disorder (ASD) in acquiring social and emotional abilities by interpreting facial expressions, modulating speech intonation, and adapting interactions based on the child's emotional and cognitive state. Their predictable responses and non-threatening, patient nature can significantly reduce anxiety and encourage communication for students who struggle in traditional settings, creating a safe space for practice. KASPAR and Keepon are also therapeutic robots used for autism intervention.

• **Individualized Education Plans (IEPs)**: Generative AI tools can assist teachers in creating customized and personalized education plans (IEPs) that align with unique student learning styles and needs.

• **Telepresence Robots**: Robots like VGo help students with physical limitations attend school and Colleges remotely and interact with their peers, promoting remote inclusion.

Conclusion

AI and robotics in education are revolutionising learning by personalising pathways, automating tasks, and developing crucial skills like problem-solving, preparing students for future jobs, but require a balanced approach that integrates technology with essential human connection, ethical considerations, and equitable access to ensure holistic growth, not just technological proficiency. The result is that these tools are powerful assistants, not replacements for teachers, creating dynamic environments that foster creativity and critical thinking while addressing unique learning needs.

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