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FUTURE SCIENCE EDUCATION WITH ARTIFICIAL INTELLIGENCE AND ROBOTIC CODING

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Introduction

In the modern global context, the production and assimilation methodology of scientific knowledge is undergoing a radical paradigm shift that is majorly catalyzed by the pervasive influence of digital technologies. The integration of Artificial Intelligence (AI) and robotic coding transcends the conventional rote-learning model in science education, establishing a dynamic learning milieu where students are actively engaged in the processes of discovery, interpretation, and creation. The intrinsic ability of AI to perform real-time analysis of individual learners' needs, together with the capability of robotics applications to make abstract scientific concepts experientially accessible, is contributing simultaneously to making the pedagogy of science both more accessible and more interactive. This chapter aims to provide a comprehensive, holistic view of what the future classroom might look like by critically exploring the many facets that these two technologies are playing in the field of science education.

What Is Artificial Intelligence? Its Role and Importance in Education

Artificial Intelligence (AI) is defined as a computer system capable of executing cognitive tasks typically associated with the human mind, including learning and problem-solving (Wartman & Combs, 2018). AI manifests human intelligence through capacities such as data analysis, learning, problem-solving, decision-making, generalization, and leveraging experience (Elmas, 2021). In essence, AI can be succinctly characterized as the capacity of computers or machines to perform behaviors that mimic human intelligence. This technology utilizes sub-specialties like Machine Learning (ML), Natural Language Processing (NLP), and Deep Learning to enable machines to execute specific tasks without human intervention (Baker & Smith, 2019). The inception of Artificial Intelligence began in the 1950s, with the term first coined by McCart-

hy (Russell & Norving, 2003). Today, AI has driven revolutionary innovations across numerous sectors, and has recently gained significant momentum and garnered considerable interest, particularly within the field of education (Richter Zawacki et al., 2019).

Artificial intelligence is increasingly being integrated into the administration, teaching, and learning processes within educational settings (Chtaskol et al., 2018). The incorporation of AI in education has the potential to personalize learning, provide more effective learning experiences, help students explore their abilities, foster creativity, and reduce teachers' workload (Haseski, 2019). By tailoring learning materials to students' individual needs and abilities, AI can create a more personalized learning journey and offer improved learning experiences (Chen et al., 2020). Such personalization enables learners to engage with content at their own pace and according to their preferred learning styles, which may enhance overall achievement. Additionally, AI-supported educational tools can offer automated feedback and promote collaboration among students—further contributing to the benefits that AI brings to contemporary education (Baker & Smith, 2019).

Artificial intelligence can be utilized in educational settings to support instructional delivery, assist teachers in managing classroom activities, and identify students' individual learning needs by diagnosing their difficulties (Çam et al., 2021). Tasks such as automated grading, assignment analysis, and monitoring student behavior in the classroom can be performed by AI systems (Baker & Smith, 2019). As a result, teachers are able to dedicate more time to meaningful, personalized interactions with students and monitor their developmental progress more closely.

Chen et al. (2020) reported evidence that applications of artificial intelligence in education have advanced far beyond the traditional perception of simple computer systems. AI is now being employed in areas such as curriculum and content development, enriching students' learning experiences and creating opportunities that extend beyond the physical boundaries of the classroom. By incorporating more complex technologies—including robotics, embedded systems, and computational tools—AI enhances the effectiveness of instructional processes. Overall, artificial intelligence brings transformative changes to the field of education, making teaching and learning more efficient, effective, and personalized.

The implementation of artificial intelligence in education not only enriches students' learning experiences but also significantly reduces teachers' workload. Automated feedback, individualized assessments, and AI-supported personalized learning pathways enable each learner to reach their full potential. Moreover, the integration of more advanced AI applications into educational processes extends beyond traditional instructional methods, enhancing classroom practices and allowing physical limitations to be overcome. Consequently, artificial intelligence offers innovative and effective educational solutions, shapes future learning environments, and holds the potential to improve student achievement levels (Gulnar et al., 2024).

Robotics Programming in Education

It would not be incorrect to state that robotic programming is a product of modern technology. Programming involves developing commands to solve a problem identified by a computer and applying these commands to reach a solution. Coding with robots allows this process to become tangible. Robotics refers to the activation of stationary robot components through technological controls (Soypak & Eskici, 2023). With the global recognition of the importance of skills such as analytical and critical thinking, reasoning, problem-solving, and design-oriented thinking, coding and robotics education is being incorporated into curricula at early ages. This enables children to develop algorithmic thinking skills through interdisciplinary interactions, thereby fostering 21st-century competencies (Goksoy & Yılmaz, 2018). Students engage in coding practice; it can be argued that this positively contributes to the development of problem-solving, creative thinking, algorithmic thinking, critical thinking, logical reasoning, classroom participation, computational thinking, and practical professional skills (Ramazanoglu, 2021). These skills are essential for students to succeed in the future labor market (Eguchi, 2016). Through robot programming activities, students have the opportunity to design and program their own robots, transforming theoretical knowledge into practical application.

The use of robots in education significantly contributes to the acquisition of higher-order thinking skills. Various studies conducted with high school students have found that robotic tools, such as Lego Mindstorms EV3, help enhance students' STEM skill levels, improve their problem-solving abilities, and positively influence their attitudes toward the course. Moreover, the utilization of robots as educational materials positively affects the learning process of individuals with special needs, while simultaneously fostering positive attitudes and improving students' computer skills. Collectively, these studies indicate that robotics education enhances students' computational thinking skills as well as their social competencies (Kaya et al., 2020; Kılıc, 2022; Kim & Lee, 2016; Ramazanoglu, 2021; Turk & Korkmaz, 2023).

Robotics programming activities enable students to apply theoretical knowledge in practice, thereby developing 21st-century skills such as problem-solving, creative thinking, and critical thinking (Karatas, 2021). Research indicates that the use of robotics in education enhances STEM skills, improves problem-solving abilities, and positively influences students' attitudes toward the course (Yalcın & Akbulut, 2021; Gezgin & Mihci, 2023), while also supporting the development of students' computer skills.

The Use of AI and Robotics in Science Education: Why Is It Important?

The 2018 Science Curriculum aims to educate individuals in the field of scientific knowledge by providing foundational knowledge, developing scientific process skills, increasing environmental awareness, enhancing problem-solving abilities, raising awareness about careers and entrepreneurship, and fostering an understanding of scientific production processes. It also seeks to cultivate interest in knowledge and natural phenomena to promote safe

working practices, improve reasoning and decision-making skills, and apply universal ethical values and principles in scientific ethics (Ministry of National Education [MEB], 2018). A key point to emphasize here is the concept of the scientifically knowledgeable individual. Scientific literacy is a process that enables individuals to effectively use scientific knowledge in all areas of daily life. This process not only involves memorizing scientific concepts but also aims to make these concepts meaningful and applicable through practical implementation (Kavak et al., 2006). The use of robotics and artificial intelligence can be effective in achieving the goals of science education. According to Sullivan (2008), learning robotics is closely linked to three fundamental objectives of scientific culture. First, robotics research requires the use of four core skills among scientifically competent individuals: computation, prediction, manipulation, and observation. Second, robotics actively engages students in the scientific inquiry process through technology design and computer programming activities. Third, robotics education provides students with in-depth knowledge about systems, which is an important topic in science education. The use of robots can yield positive outcomes not only in achieving educational objectives but also in fostering a positive attitude toward science courses (Guven & Sulun, 2020).

The use of digital technologies, such as artificial intelligence (AI), in science education plays a significant role in enabling students to learn scientific concepts more easily, effectively, and engagingly. AI has the capability to collect, analyze, and interpret data obtained by students from scientific experiments (Kızılay, 2023). Another important benefit of using AI and robotic technologies is the provision of personalized learning opportunities. Since each student has a different learning pace and style, these technologies can offer educational programs tailored to individual needs. AI-based educational systems can analyze students' learning outcomes, identify gaps, and provide appropriate, personalized learning pathways to support their development. This approach can be particularly beneficial in knowledge-intensive fields like science education, helping students to learn more effectively and improve their academic performance.

From the educators' perspective, artificial intelligence (AI) and robotic technologies can make the teaching process more effective. For instance, with AI-based tools, teachers can monitor students' learning more closely and intervene more quickly when necessary. Systems that provide automatic assessment and feedback reduce teachers' workload, allowing them to devote more time to direct interaction with students. Additionally, by using AI and robotic tools, teachers can make science topics more dynamic and engaging, which can, in turn, enhance students' motivation to learn.

Artificial intelligence (AI) and robotic technologies play a vital role in fostering 21st-century skills. In today's workforce, skills such as technological literacy, problem-solving, analytical thinking, and the ability to generate creative solutions are highly valued. Students who engage with AI and robotic tools during science education have the opportunity to develop these skills

from an early age. This, in turn, helps prepare them for future careers and equips them with a stronger technological proficiency.

The use of artificial intelligence (AI) and robotic technologies in science education provides significant benefits for both students and teachers. These technologies can make learning experiences more effective and engaging, increasing students' interest in science and transforming them into more motivated and engaged learners. Additionally, by offering opportunities for problem-solving, critical thinking, and interdisciplinary learning, they help prepare students for their future careers. Therefore, the integration of AI and robotic technologies into science education should be considered an essential component of modern education and promoted widely.

The Significance of Robotics Programming in STEM Education

In contemporary education, STEM (Science, Technology, Engineering, and Mathematics) fields stand out as an interdisciplinary approach aimed at developing students' problem-solving, critical thinking, and innovation skills (Akdur et al., 2024; Erdogan et al., 2017; Hernandez, 2014). The goal of education in these fields is to ensure that students not only understand theoretical concepts but also apply them to real-world problems (Thomasian, 2011). According to Cameron (2005), robotics programming is becoming a significant tool in STEM education. Robotics programming can enhance students' creative thinking abilities and their skills in actively utilizing technology, thereby increasing their interest in STEM disciplines (Cakir, 2020). For example, a line-following robot project can help students learn basic programming skills and understand how technological components, such as motors and sensors, function. This project will teach students the stages of the engineering design process and how to use mathematical concepts to optimize the robot's movement. In this way, theoretical mathematics and engineering skills can be transformed into practical experience.

Robotics programming also enhances students' connections with the sciences (Altin & Pedate, 2013). For example, robotic projects can interact with the environment using sensors such as light, distance, and temperature sensors. Such applications develop students' abilities to collect and analyze scientific data (Koc & Buyuk, 2014). A robot project that measures environmental changes allows students to formulate hypotheses and evaluate their results, enabling them to apply scientific approaches (Koc Senol, 2012).

Robotics programming provides students with experience in computer science and software development from a technological perspective. In such projects, algorithmic thinking skills and programming languages are crucial. Acquiring various skills, from creating algorithms to debugging, is necessary to write code that enables the robot to perform the desired tasks (Ozdinc & Mumcu, 2022). Robotics programming also makes a significant contribution to STEM education. In robot design, students follow engineering processes such as planning, prototyping, testing, and improvement (R. Elmas, 2022). This approach can help students gain a realistic understanding of how engineering disciplines work, preparing them to become the engineers of the future.

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Investigating Science Through Robotics-Based Activities

One of the fundamental disciplines that helps us understand how nature works is science. However, teaching the theoretical topics of these disciplines in the classroom can sometimes be challenging (Lacin Simsek, 2020). Robotics projects can serve as an excellent tool to make scientific concepts more engaging and easier to understand.

Robotic applications can make learning and exploring core subjects such as physics, chemistry, and biology enjoyable. A simple balance robot, for example, can be used to observe Newton's laws of motion. While controlling the robot's movement, students can observe the relationship between force and acceleration, thereby learning these concepts. Such projects transform abstract concepts into tangible experiences and can enhance students' scientific process skills. In his study, Kirtay (2019) investigated the effects of robotics applications on students' scientific process skills (observation, measurement, classification, recording data, formulating hypotheses, using data and modeling, manipulating and controlling variables, conducting experiments) and motivation toward science education in the Force and Motion unit (MEB, 2018). The results indicated that robotics applications facilitate learning and contribute to the development of scientific skills.

In chemistry lessons, it is possible to measure the temperature, pH, and humidity levels of various environments using robotic sensors. By analyzing the data collected by their robots, students can learn about the effects of environmental changes on chemical processes. This provides knowledge of scientific research methods and develops critical skills such as data collection and analysis. Robotics can also be used in exploring biology. For example, biomimetic projects have the potential to produce robots that imitate the movements of living organisms in nature. These projects can be used to teach the mechanics of muscles and joints. A robot simulating an animal's walk can help students better understand the functioning of the muscular and skeletal systems.

Robotics projects contribute to the education of STEM (Science, Technology, Engineering, and Mathematics) fields. These projects teach students both theoretical and practical knowledge (Altunel, 2018). To learn more about renewable energy sources and energy transformations, students can design

a solar-powered robot car. Such projects can also teach the concept of sustainability by enabling people to gain more knowledge about the environment. According to K. Simsek (2019), robotics projects bring science out of the classroom and make learning an active process. This not only helps students develop their scientific skills but also enhances their ability to solve future problems using technology (Cam, 2019). Exploring science through robotics projects can make education more lively, interactive, and inspiring, opening new horizons for students.

Implementing Artificial Intelligence and Robotics Programming in Classroom Settings

Robotics programming and artificial intelligence (AI) are gaining increasing importance in education as technology rapidly advances (Akdeniz & Ozdinc, 2021; Yildiz Durak, 2020). These innovative tools can help students improve in areas such as science, mathematics, and engineering, and can transform the in-class learning experience (Demircioglu et al., 2024; Koray & Uzuncelebi, 2023; Seckin Kapucu, 2023; Tekin & Keser, 2020). Robotics programming and AI can make classroom instruction more interactive and student-centered. Here are some examples of in-class applications of artificial intelligence (AI):

Personalized Learning with Intelligent Learning Systems: AI-supported intelligent learning systems adapt to students' learning styles and paces (Baker & Abu-Naser, 2019). These systems can identify students' strengths and weaknesses and provide personalized instructional content. For example, an AI system can offer additional topics for students struggling in mathematics, thereby providing a personalized learning experience.

Automated Assessment and Feedback: AI-supported automated assessment tools accelerate the evaluation process of exams or assignments. These tools can analyze students' responses and provide instant feedback to both teachers and students. This allows students to quickly identify areas in which they are deficient and makes the learning process more efficient.

Chatbots and Digital Student Assistants: Chatbots are AI-powered conversational agents designed to interact with humans through visuals, voice messaging, or text (Baris, 2020). Students can receive assistance from AI-based chatbots and digital assistants outside of class. These tools continue the learning process by answering students' questions and enabling faster acquisition of information (Kane, 2016). For example, students can ask their digital assistant about the causes of a war in history class and receive an immediate response.

Content Creation and Language Processing: Natural Language Processing (NLP) is the area of AI that enables computers to understand, analyze, and emulate human language (Korkmaz, 2023). Text analysis and NLP techniques can also assist in the creation of instructional materials. AI-supported tools can speed up teachers' processes in preparing lesson notes or exam questions.

Applying Robotics Programming in Classroom Settings

Robotics programming is particularly important in STEM (Science, Technology, Engineering, and Mathematics) courses because it enables students to transform theoretical knowledge into practical skills (Ouyang & Weiqi, 2024). In-class robotics programming helps students develop problem-solving, creative thinking, and coding skills (Alboria & Alsaleh, 2022). The use of robotics programming in the classroom can be implemented as follows:

***Hands-On Project-Based Learning*:** Robotics programming allows students to work on real-world tasks. For example, students can design a simple robot and program it to perform a specific task. In this process, students develop both coding language skills and algorithmic and logical thinking abilities (Castelblanco et al., 2019). Completing tasks such as moving the robot along a specific path or transporting objects can help enhance students' coding and engineering skills.

***Robot Competitions and In-Class Activities*:** Students can apply the knowledge they have learned through robot competitions and classroom activities (Kaji et al., 2019). Competitions not only foster teamwork and collaboration skills but also increase students' motivation (Huei Chen et al., 2020). Students attempt to program their robots to complete tasks within a given time frame, making learning more engaging and competitive.

***Coding and Robotics Workshops*:** Schools can support students' engagement with robotics programming outside of class. In these workshops, students can work on more complex projects to further develop their knowledge and skills. Such activities can capture students' interest and enhance their curiosity toward science and technology.

Challenges and Considerations in Robotics Programming

Robotics programming and artificial intelligence offer great opportunities for in-class applications, they also present certain challenges. For these technologies to be used effectively in the classroom, teachers must possess sufficient knowledge and skills (Schina et al., 2021). Additionally, it is crucial to provide schools with the necessary infrastructure and resources for such applications (Akcay et al., 2019; Aydogan, 2021; G. Guven & Cakir, 2020). In locations with limited technological resources, ensuring equal educational opportunities for all students can be difficult.

Educational Benefits of Interactive Learning through Artificial Intelligence and Robotics

Robotics and artificial intelligence (AI) are important tools for enhancing interactive learning in education and enabling students to actively participate in the learning process (Caka, 2022; Nalbant, 2021). These technologies allow students to develop their cognitive skills and gain deeper access to knowledge.

Enhancing Creativity and Critical Thinking: Robotics and artificial intel

ligence (AI) help students develop their critical and creative thinking skills (E. Altun, 2024; Kucukaydin & Bor, 2021). Robotics projects provide students with opportunities to solve challenging problems and generate novel solutions (Gezgin & Mihci, 2023).

***Developing Teamwork and Collaboration Skills*:** Robotics projects typically require group work. This helps students improve their communication, collaboration, and teamwork skills (Gezgin et al., 2022). By combining different perspectives, students can produce innovative solutions (Tatlısu, 2020).

***Acquiring 21st Century Skills*:** Robotics and AI provide students with the opportunity to acquire essential 21st-century skills. Competencies such as technological literacy, problem-solving, communication, and critical thinking are highly valued in today's workforce (F. Erdogan, 2023). Therefore, AI and robotics applications help prepare students for their future careers.

Creating interactive learning experiences for students using robotics and AI not only enhances instruction but also increases students' active engagement, providing a more effective learning environment. Educators' effective use of these technologies in the classroom positively impacts students' learning experiences and prepares them for the future.

Creating a Science Education Curriculum Integrating Artificial Intelligence and Robotics Programming

With the rapid advancement of technology and digitalization in recent years, significant changes have occurred in education (Surer, 2020). The approach to science education has also evolved as a result of these changes. Robotics programming and artificial intelligence (AI) play an important role in renewing science education to meet the demands of the current era (Erdogan, 2023). Therefore, AI and robotics programming courses in science education can be crucial for helping students develop scientific thinking skills and prepare for the digital world.

Robotics programming and AI facilitate the development of skills such as problem-solving, critical thinking, creativity, and collaboration (M. Altun et al., 2023; Anilan & Gezer, 2020). Science education aims to equip students with the ability to use evidence, reason inductively and deductively, classify, make scientific predictions, formulate hypotheses, conduct experiments, draw scientific conclusions, develop scientific models, and engage in scientific inquiry (MEB, 2020). In this context, AI and robotics programming serve as effective tools to support the acquisition of these skills.

The use of AI in science education enables students to enhance scientific process skills such as data collection, analysis, and interpretation (Sarioglu, 2023). For example, students can analyze the effects of environmental variables using sensors (V. Kilic, 2021). Additionally, by learning data classification and modeling processes through AI tools, students can gain a deeper understanding of scientific methods (Diyer et al., 2022).

On the other hand, robotics programming allows students to apply concepts learned in science and participate in the engineering design process (Ucar & Sezek, 2024). Through robotics projects, students can connect the digital and physical worlds. For instance, by programming robots, students can directly observe and experiment with the effects of electrical applications while studying electrical circuit components. Such applications enable students to apply theoretical knowledge in practice and promote lasting learning (B. Kaya & Bozyigit, 2024).

Development of the Curriculum: Key Principles and Learning Objective

In designing a curriculum for artificial intelligence (AI) and robotics programming in science education, certain principles and objectives should be considered. These principles include:

- **Hands-On Learning and Experiential Engagement:** The curriculum should include activities that promote active student participation and enable learning through experience (Hancer et al., 2003). Robotics programming and AI projects facilitate students' understanding of science concepts (Erdogan, 2023; Erten, 2019).

- **Development of Scientific Thinking Skills:** Students should be provided with foundational knowledge about analytical thinking, problem-solving, scientific inquiry, as well as AI algorithms and robotic systems.

- **Technological Literacy and Digital Skill Development:** Integrating robotics programming and AI into education equips students with essential skills for the digital age. Students who learn to use technology can generate innovative solutions and navigate the modern world with confidence (Et & Gomleksiz, 2023).

- **Interdisciplinary Approach:** The curriculum should create connections among various disciplines, such as science, mathematics, computer science, and engineering, allowing students to integrate knowledge from multiple domains (Bati et al., 2017). This enables students to approach complex problems with a broader perspective (Sultan Qurraie, 2024).

- **Ethics and Social Responsibility Awareness:** Given the societal impact of robotic systems and AI technologies, students should act with a sense of ethical responsibility (Efe, 2021). Education should address both the advantages and disadvantages of AI to raise awareness among students.

The AI and robotics programming curriculum should be structured to suit students at different levels and include a variety of topics. Some key topics and learning activities that can be incorporated into the curriculum include:

- **Fundamentals of Artificial Intelligence:** This section provides information on the emergence of AI, fundamental concepts, and various application areas. Students need to understand the basic operating principles and how AI is applied in everyday life.

Machine Learning and Data Analysis: Basic machine learning algorithms and simple data analysis techniques can be introduced. These activities provide students with foundational skills in data collection, analysis, and model building. Connecting these concepts to experimental data used in science classes can make the learning experience more meaningful.

Fundamentals of Robotics and Programming: Core concepts such as sensors, actuators, and robot components can be taught. Additionally, students can gain knowledge about robotic programming languages and platforms, which enables them to build and program simple robots.

Projects and Experiments: Students should be given the opportunity to work on robotics- or AI-based projects. Such projects allow for the practical application of theoretical concepts and encourage creative problem-solving.

Ethical and Societal Issues: The societal impact and ethical concerns of technologies like robotics and AI can be discussed. This helps students understand the social and moral implications of technology on human life.

During the implementation of an AI and robotics programming curriculum in science education, certain challenges may arise. Key challenges include teachers' insufficient technological knowledge and the lack of infrastructure in schools (Kuzgun & Ozdinc, 2017). To address these issues, the following recommendations can be made:

- **Teacher Training and Professional Development:** Training programs on robotics programming and AI should be developed for teachers. These programs enable teachers to effectively guide students using technology (Sayin, 2020).

- **Improving Infrastructure:** Schools should be provided with the necessary software and hardware infrastructure to implement the curriculum effectively (Ceylan & Gundogdu, 2018). This includes programming platforms, AI software, and robotics kits.

- **Interdisciplinary Collaboration:** Collaboration among teachers from different disciplines allows for a more comprehensive and effective curriculum implementation (Bakar, 2023). Cooperation between technology, science, mathematics, and computer science teachers should be encouraged.

- **Interactive and Student-Centered Learning Environments:** Interactive learning environments should support experiential and hands-on learning. This increases student engagement and promotes more lasting learning outcomes (Dogac & Gok, 2020).

Robotics programming and AI introduce a novel approach to science education and serve as important tools for developing 21st-century skills (Celık, 2021). Integrating these technologies into science education helps students enhance scientific thinking skills and prepares them for the digital world. For successful curriculum implementation, attention must be paid to teacher training, school infrastructure, and interdisciplinary collaboration. Effectively

implementing AI and robotics education programs is a crucial step toward cultivating future scientists and individuals prepared for a technology-driven world.

Example for curriculum

Level: 6thGrade

Duration: 4 weeks (8 lessons

Core Science Learning Outcomes:

- Explain the difference between heat and temperature.
- Propose solutions to everyday problems related to heat insulation.

Table 1: *Integrated Skill Areas*

Area	Objective
Science	Scientific process skills (observation, experimentation, analysis)
Technology	Sensors, data collection systems
Engineering	Design of insulated models
Mathematics	Data analysis, graph interpretation
Artificial Intelligence	Algorithms that make decisions based on temperature data
Robotics & Coding	Systems integrating temperature sensors and motors

Week1: Concept Exploration and Experimentation

Activities:

- Demonstrate the difference between heat and temperature through experiments.
- Examine Arduino-based temperature sensors.
- Discuss how data is measured and collected.

AI Integration:

- Convert sensor data into graphical representations.
- Pattern recognition in data (e.g., under which conditions does the temperature rise accelerate?).

Week2: Engineering Design

Activities:

- Design a mini greenhouse or “food container” to provide heat insulation.

- Discuss material selection and AI-assisted proposals for "models that reduce heat loss."

AI Integration:

- Develop simple decision-making algorithms (if-then conditions) that evaluate the insulation efficiency of different materials.

Week 3: Robotics and Coding Application

Activities:

- Students program a warning system using a temperature sensor.
- Objective: Motor activates or LED lights up when a certain temperature is exceeded.
- Scratch or mBlock can be used.

AI Integration:

- Include "simple recommendation systems analyzing temperature data" in the code (e.g., "If the temperature continuously rises over x days, trigger a warning").

Week 4: Project Presentation and Evaluation

Activities:

- Students present their projects.
- Determine which model provides the best insulation.
- Examine how AI decisions interact with the robotic system.

Assessment Criteria:

- Scientific explanation competence
- Coding accuracy
- Explainability of AI-based decision logic
- Group collaboration and presentation skills

Additional Learning Outcomes:

- 21st-century skills (critical thinking, creativity)
- Problem-solving
- Data literacy
- Basic AI literacy
- Recognition and control of robotic system components

Emerging Trends in Education and Strategies for Technological Integration

The rapid advancement of technology has led to a significant transformation in the education sector today (Eser, 2014). Digitalization, AI-supported education, and personalized learning are new trends that are surpassing traditional educational approaches (Ekin, 2022). These innovations can make learning more effective and efficient (Parlak, 2017). Emerging trends in education and approaches to technological integration are reshaping students' access to knowledge, the role of teachers, and the time and place of learning (Ryan & Bagley, 2015).

Emerging trends in education are practices that arise alongside technological opportunities, making learning processes more flexible, accessible, and personalized. Some of the prominent trends in contemporary education include:

- **Personalized Learning:** This approach tailors education to each student's learning pace, interests, and needs. It enables students to manage their learning processes more effectively and achieve their goals. Adaptive learning systems and AI-based educational platforms support personalized learning (Yoruk, 2024).

- **Remote and Hybrid Learning:** Rapidly adopted during the COVID-19 pandemic, remote and hybrid learning allows students to combine online and face-to-face educational opportunities. Hybrid learning models provide teachers the chance to integrate different teaching methods while offering students a flexible learning experience (Goksel & Adiguzel, 2024).

- **Game-Based and Gamified Learning:** Incorporating game elements (points, rewards, levels) into lesson content makes learning more enjoyable and motivating. Game-based learning directly utilizes digital games designed for educational purposes, while gamification applies game mechanics to conventional learning (Kirmaci & Cakmak, 2022; Bayirtepe & Tuzun, 2007). These approaches increase student engagement and make the learning process more interactive (Bolat et al., 2017; Ulkudur, 2016).

- **AI-Supported Education:** Artificial intelligence plays a crucial role in monitoring student performance, providing feedback, and enabling personalized learning experiences. AI-powered educational systems assess students' strengths and weaknesses and provide tailored content and learning paths (Isler & Kilic, 2021).

- **Virtual Reality (VR) and Augmented Reality (AR):** AR and VR technologies help students better understand lessons and enhance their learning experiences (Shelton & Hedley, 2002; Tepe et al., 2016). For example, students can explore a virtual model of the human body in biology or participate in a virtual tour of ancient civilizations in history classes.

- **Social and Emotional Learning (SEL): S**EL focuses on developing students' social skills and emotional intelligence. It aims to teach self-regulation, collaboration, empathy, and problem-solving skills, fostering a more inclusive and supportive learning environment (Aygun, 2019).

The effective use of technology in education requires redesigning teaching strategies and adapting digital tools to learning environments (Koyuncuoglu & Taspinar, 2024). Key factors for successful technological integration in education include:

- **Selection of Digital Tools and Platforms:** Digital tools and platforms used in education should meet students' needs and support learning objectives. Teachers need to understand how to integrate various digital tools into lesson content and maximize the benefits of the features they offer.

- **Teacher Training and Professional Development:** For successful technology integration in education, teachers must be equipped and skilled to implement these tools effectively in the classroom.

In conclusion, continuous professional development programs should be organized and support should be provided to enable teachers to use technology effectively. Teachers who are experts in educational technologies are better equipped to guide students in utilizing digital tools to meet the demands of the modern era (Metin, 2018).

Content Development and Adaptation: Lesson content to be used in digital environments should be adapted to provide meaningful and effective learning experiences for students. Educational materials should be revised and updated as necessary, considering the interactivity and visual advantages offered by digital tools (Cevik et al., 2024).

Digital Security and Ethical Use: The use of technology in education also requires raising students' awareness of digital security and ethics. Students should be taught how to navigate online environments safely, use digital tools responsibly, and protect their personal data (Sahin et al., 2022).

Creating Interactive and Participatory Learning Environments: Technology enables students to participate more actively in interactive learning environments. Applications such as AR, virtual classrooms, digital simulations, and game-based learning enhance students' engagement and involvement in lessons (Bahsi & Gencer, 2024).

Technological integration in education provides significant benefits for both students and teachers. These benefits help make learning easier, more efficient, and more effective (Doger, 2016):

- **Personalization of Learning Processes:** Technology allows students to progress at their own pace by offering personalized learning paths. AI-supported educational tools and adaptive learning systems provide content and recommendations tailored to students' needs (Gunduz, 2023).

- **Easy Access to Information and Flexibility:** Digital platforms give students access to information anytime and anywhere (M. E. Simsek, 2024), making learning independent of spatial and temporal constraints (Depe et al., 2023). This is particularly advantageous in an era with remote and hybrid learning models.

- **Increasing Student Engagement and Motivation:** Interactive digital tools and gamification techniques enhance students' interest in lessons and encourage more active participation in the learning process. Technologies such as game-based learning and AR make lessons more engaging and enjoyable (R. Cakir et al., 2015).

- **Feedback and Performance Monitoring:** Digital tools allow students to receive immediate feedback, enabling them to manage their learning more effectively. Additionally, teachers can easily monitor students' progress and provide additional support when necessary (Çapar, 2024).

During the process of technological integration in education, some challenges and obstacles may arise. The following strategies can be developed to overcome these issues:

- **Infrastructure Deficiencies:** In some schools, digital infrastructure and access to technology may be insufficient (Akıncı & Tunç, 2021). To address this, government support, public-private partnerships, and cost-effective technological solutions can be utilized.

- **Educators' Adaptation to Technology:** Effectively using technology can be challenging for some teachers. Therefore, continuous professional development and technology training should be provided (Başaran et al., 2021).

- **Digital Inequality:** Students' access to the internet and digital tools may vary (Çapar, 2024). Schools can address this issue by providing students with services such as tablets, laptops, and internet access.

- **Digital Security and Data Privacy:** The widespread use of technology in education raises concerns about the security and protection of student data (Çapar, 2024). Educational institutions should train students in online safety and strengthen digital security measures.

New trends in education and approaches to technological integration can make learning more dynamic, interactive, and efficient. In shaping future educational models, it is crucial to create learning environments that meet students' needs and to leverage the opportunities provided by technology effectively.

Teaching Students Ethical and Responsible Technology Use

Robotics and artificial intelligence (AI) are becoming increasingly prevalent in education and daily life. Although these technologies hold significant potential, ethical and appropriate usage issues are crucial. Teaching students how to use these technologies responsibly is essential for enabling them to make informed decisions in the future.

The Importance of Ethical and Responsible Technology Use

- **Informed Usage:** AI and robotics are complex systems that involve data analysis, decision-making, and automation processes. Using these systems ethically ensures that students can interact with technology consciously. It is

critical for students to understand how these technologies work, as well as their benefits and potential harms.

- **Social Responsibility:** AI and robotic systems can significantly impact society. Encouraging students to consider the effects of these technologies on humans fosters social responsibility (Yar Sevmiş, 2023). For instance, discussing the impact of robots on the workforce or the data privacy implications of AI systems can engage students more deeply with these issues.

- **Decision-Making Skills:** Teaching students ethical decision-making techniques prepares them for challenges they may face in the future (Kiranli Güngör & İlğan, 2007). Discussing ethical dilemmas related to AI and robotics can enhance students' problem-solving and analytical thinking skills.

Methods for Teaching Ethical and Responsible Technology Use

- **Project-Based Learning:** Students can experience ethical issues concretely through AI and robotics projects. They should consider how a robot interacts with humans and the ethical dimensions of those interactions. Project-based learning encourages critical thinking and idea generation (Yanarateş, 2022).

- **Scenario Analysis:** Ethical dilemmas help students develop critical thinking skills. By discussing potential ethical problems related to AI applications or robotic systems, students learn to evaluate different perspectives. For example, they might debate how autonomous vehicles should behave in accident scenarios.

- **Virtual Discussions and Forums:** Organizing virtual discussions and forums allows students to explore ways to use technology ethically. These platforms enable students to listen to peers' viewpoints, share their own, and develop diverse perspectives.

- **Gamification:** Game-based learning can make understanding ethical technology use more engaging. For example, AI simulations can be used to design games in which students must make decisions according to specific moral standards, making learning more interactive and enjoyable.

Implementation Recommendations:

- **Integrate into Lesson Plans:** Incorporating content on ethical and responsible use into AI and robotics courses ensures a comprehensive treatment of the topic.

- **Conduct Virtual Workshops:** Students can learn practical ways to use robotics and AI technologies through virtual workshops, which should also address ethical issues.

- **Collaboration with Parents:** Parents play a crucial role in their children's technology use. Informative seminars can be organized to raise parental awareness about responsible technology use.

Teaching students the ethical use of AI and robotic technologies helps them grow into responsible and conscious individuals. Educators' efforts in this area support the development of students who can use technology effectively, responsibly, and morally.

Conclusion

Artificial intelligence (AI) and robotic coding in science education serve as essential tools for developing students' scientific thinking, problem-solving, creativity, and digital competencies. These technologies enable students to acquire scientific process skills such as data collection, analysis, modeling, and experimentation, while also facilitating the practical application of theoretical knowledge. In designing the curriculum, principles such as experiential learning, interdisciplinary approaches, ethical awareness, and technological literacy should be prioritized. Furthermore, teachers' technological proficiency, the schools' infrastructure, and interactive learning environments are critical factors for the successful implementation of the curriculum. Emerging educational trends, including personalized learning, hybrid education, gamification, AI-supported instruction, and virtual and augmented reality applications, enhance learning effectiveness and motivation, while digital security and ethical responsibility remain essential for fostering students' conscientious use of technology. Thus, integrating AI and robotic coding into science education provides a holistic approach that prepares students for both scientific and societal challenges in the future.

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