Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 9, S. 191-202, 3, 2025

Araştırma Makalesi

IJANSER
https://as-proceeding.com/index.php/ijanser
ISSN:2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 9, pp. 191-202, 3, 2025

Research Article

Teaching Robotics in Education 4.0

Veronika Gabaľová*

Department of Mathematics and Computer Science, Trnava University, Trnava, Slovakia

(veronika.gabalova@truni.sk) Email of the corresponding author

(Received: 04 March 2025, Accepted: 07 March 2025)

(4th International Conference on Recent Academic Studies ICRAS 2025, March 04-05, 2025)

ATIF/REFERENCE: Gabaľová, V. (2025). Teaching Robotics in Education 4.0. *International Journal of Advanced Natural Sciences and Engineering Researches*, 9(3), 191-202.

Abstract – Robotics education plays a key role in the Education 4.0 paradigm in developing digital competencies and meeting future labor market expectations. The integration of new technologies, such as artificial intelligence (AI) and microcontrollers at different levels of education, enables the development of algorithmic thinking, problem solving and creativity. The use of robotics tools and block-based programming in primary school education helps to develop students' logical skills. During secondary school studies, students can gain deeper knowledge about the operation of microcontrollers and AI-based systems, which lays the foundation for interest in technological careers. At the university level, robotics education is expanded with complex engineering, IT and biotechnology applications, facilitating the development of industrial automation, healthcare robotics and autonomous systems. The digital transformation of the learning environment supports the acquisition of interdisciplinary knowledge, while promoting the development of a lifelong learning approach. The goal of Education 4.0 is to enable students to become active, innovative, and competitive players in technological development with the help of AI and robotics.

Keywords – Robotics, Teaching Robotics, Education 4.0, AI, Flipped Classroom, Blended Learning.

I. INTRODUCTION

Education 4.0 is a new educational paradigm that has emerged as a result of the digital revolution, adapting learning processes to industrial and technological developments. Modern educational methods aim to equip students with skills that meet the demands of the future labor market, while becoming active and creative actors in technological innovation. The integration of robotics, artificial intelligence (AI), and microcontrollers into education provides essential tools for the development of algorithmic thinking, problem-solving, and interdisciplinary knowledge [1].

Robotics education provides opportunities to develop logical skills from elementary school level, and in high school, it offers deeper technological knowledge and practical experience. During university-level training, students can work with complex systems, the applications of which include industrial automation, healthcare robotics, and the development of autonomous systems.

New teaching methods, such as blended learning and flipped classroom, offer opportunities to make robotics education more effective. These approaches promote active participation, independent learning, and the development of practical skills. Education 4.0 aims not only to transfer technological knowledge, but also to develop a mindset that promotes innovation and lifelong learning [2][3].

II. LEVELS OF ROBOTICS EDUCATION

A. Primary Education

Introducing robotics education at the primary school level is important, as children at this age are extremely receptive to new knowledge and easily acquire basic logical and problem-solving skills. The playful approach to robotics and programming helps develop creativity, critical thinking and algorithmic thinking, which will later be essential in technology-based workplaces and everyday life.

Fundamentals of Robotics and Programming

In primary school education, the emphasis is on block-based programming, which allows algorithms to be built using visual elements. Programming environments such as Scratch, Blockly or Open Roberta allow children to easily create commands and control virtual or physical robots without writing code. These tools help students develop algorithmic thinking, while receiving immediate feedback on the operation of their own programs [4].

Robotic tools in primary school

Physical interaction is particularly important for students, so programmable robots and construction toys are widely used in education, which provide a tangible experience:

- Bee-Bot – A simple, button-programmable robot that helps even the youngest children learn directions, coherent thinking, and basic programming skills in an understandable way.
- LEGO Education (WeDo, Mindstorms) – Through the combination of construction and programming tasks, students not only develop their understanding of mechanical structures, but also become familiar with the basics of programming.
- mBot – An easy-to-assemble robotic device that teaches children how sensors, motors, and basic algorithms work through Scratch-based programming.
- Robo Wunderkind, Ozobot – Creative and interactive robots that introduce them to the world of robotics and programming in a playful way [5].

Teaching methods and pedagogical approaches

Robotics education in primary schools differs from traditional subject teaching in that it is often based on project-based and exploratory learning. The most important methods include:

- Playful learning – Students learn the basics through various challenges and playful tasks, such as planning a robot's path, guiding it through a maze, or programming movement patterns [6][7].
- Project-Based Learning (PBL) – Students work in teams on a specific problem or task, such as building and programming a robot that can perform a specific task (e.g., avoiding obstacles).
- Blended Learning – Combining online learning materials with hands-on activities using physical devices, allowing students to explore the basics independently and at their own pace [8].
- Flipped Classroom – After studying theoretical materials (videos, interactive courses) at home, students can focus on solving practical problems and experimenting in class [9].
- Gamification – Motivating students with a reward system and competitions, such as robot programming challenges or hackathons [10][11][12].

The role of robotics in skill development

Working with robotics develops several key competencies for primary school students:

- Logical and algorithmic thinking – Understanding the sequence of commands and steps.
- Problem solving – Troubleshooting, experimenting and iterating during programming.
- Creativity and innovation – Designing and implementing their own robot projects.
- Teamwork and communication – Strengthening collaboration through group tasks and competitions.
- Digital literacy – Confident use of technological tools and software [13].

Student motivation and future impact

Early introduction to robotics helps to spark students' interest in STEM (Science, Technology, Engineering, Mathematics) fields, thereby increasing their later educational and career opportunities. This type of education contributes to the development of a lifelong learning mindset, which is essential for thriving in a rapidly changing technological environment [14]. Educating students in robotics in primary schools not only develops technological skills, but also shapes the way they think. The combination of block-based programming, physical robots, and innovative teaching methods allows children to learn about the workings of the digital world creatively, independently, and in teams. In the spirit of Education 4.0, the goal is for all students to step into a technology-defined future prepared and confident [15][16].

B. Secondary Education

The aim of secondary education in robotics is to provide students with a deeper understanding of technology and programming, while gaining hands-on experience in the application of microcontrollers, artificial intelligence (AI), and sensor technologies. At this age, there is a greater emphasis on independent problem solving, the development of engineering thinking, and an understanding of the connections between different disciplines.

Robotic tools and programming

In secondary education, students are introduced to more advanced programming languages and hardware tools that form the basis of technologies widely used in industry and academia.

- Microcontrollers and development platforms
    - Arduino – An easily programmable microcontroller that can be used to control sensors and actuators, making it ideal for robotics projects [17][18].
    - Raspberry Pi – A miniature computer that allows students to perform more complex programming and networking tasks [19][20].

Artificial Intelligence and Sensor Technology

High school robotics education is increasingly integrating the principles of artificial intelligence and the use of sensor technologies. This not only develops students' analytical and algorithmic thinking, but also prepares them for the application of AI-based systems during their university studies and in the job market.

- Machine learning basics – Building AI models on simpler platforms (e.g. Google Teachable Machine, Edge Impulse) [21][22].
- Image processing and facial recognition – Using OpenCV and AI algorithms using Raspberry Pi or Jetson Nano [23].
- Sensors and data processing – Using temperature, distance, accelerometer and other sensors in data analysis and automated systems.

Teaching methods and pedagogical approaches

In high school robotics education, traditional classroom instruction is combined with innovative methods that promote the development of practical skills and creative problem solving.

1. Project-Based Learning (PBL)
    - Students find solutions to real-world problems, for example by developing a smart home automation system or a self-driving vehicle.
    - Students work in teams, which also improves their collaboration and communication skills.
2. Blended Learning
    - Theoretical knowledge is acquired through online learning materials, while classroom lessons focus mainly on practical application [24][25][26].
    - Platforms such as Coursera, edX or Udemy allow students to deepen their knowledge independently.

3. Flipped Classroom
- Students learn theoretical material at home (via videos, interactive courses) and then apply the acquired knowledge in class through group projects and experiments.
- This method promotes active learning and the development of problem-solving skills [27].

Student motivation and career orientation

One of the most important effects of secondary school robotics education is to increase students' motivation and interest in STEM (science, technology, engineering, mathematics) fields. Through practical experiences and interactive learning methods, students can more easily decide whether they want to enter a career in engineering, IT or other technology. High school robotics education plays a critical role in preparing students for technology. The introduction of microcontrollers, AI algorithms, and sensor technologies allows students to put their theoretical knowledge into practice. Innovative teaching methods, such as flipped classrooms and blended learning, promote independent learning and active participation. The goal of robotics education is to help students confidently use modern technologies and prepare them for the digital economy.

C. University-level education

The aim of university-level robotics education is to provide students with in-depth knowledge in the application of advanced engineering, IT and artificial intelligence technologies. At this level, learning is already interdisciplinary, combining the disciplines of mechanical engineering, electronics, data processing and autonomous systems. Students not only acquire theoretical knowledge, but can also contribute to the development of robotics and industrial automation with their own innovative research and development.

Industry 4.0 and Education 4.0 are closely linked, especially from the perspective of university education, as technological developments not only transform industrial processes, but also present the education system with new challenges and opportunities. Industry 4.0 means the digitalization, automation and integration of manufacturing and services with intelligent systems, which is based on technologies such as artificial intelligence, machine learning, IoT, robotics and big data. These changes are fundamentally shaping the labor market, making it essential for universities to adapt to new demands and provide students with the competencies needed to enter the workplaces of the future [28][29].

Education 4.0 refers to the digitalization of teaching methods, increasing their interactivity and providing personalized learning experiences. The goal is for university education to keep pace with technological developments and develop skills such as problem solving, creativity and digital competence. Characteristics of Education 4.0 include technology-based teaching, such as the use of virtual and augmented reality (VR, AR), IoT, artificial intelligence and big data in education. In addition, practice-oriented learning, which includes project-based learning, simulations and solutions based on real industrial challenges, is gaining an increasing role. Adaptive learning platforms and AI-based personalized learning enable students to progress according to their individual needs, while digital tools and remote learning opportunities increase interactivity and collaboration [30]. University education must adapt to these changes, which requires a number of reforms in teaching methods and the design of learning materials. Digital and hybrid education is increasingly gaining prominence, complementing traditional teaching forms with online courses, virtual labs and automated assessment systems. An interdisciplinary approach is also becoming essential, as different scientific fields such as computer science, data management and biotechnology are increasingly intertwined in industry. New competencies such as digital literacy, data-driven decision-making, creative problem solving and innovation are increasingly emphasized in university education. The strengthening of the practical approach to education will also lead to closer cooperation between universities and industry, which can be achieved through dual training, industrial projects and internships [31]. Although Industry 4.0 and Education 4.0 offer many opportunities for university education, they also face serious challenges. One of the biggest tasks is to develop the digital competences of lecturers and students, as well as to modernize university

infrastructure. In addition, the continuous updating of curricula and adaptation to rapidly changing industrial expectations are also critical factors. However, in parallel with these challenges, many benefits are emerging, such as the strengthening of cooperation between industry and universities, the creation of innovative learning environments and the spread of flexible, personalized education [32].

Robotic Systems and Technologies in University Education

During their university studies, students learn about robotics platforms and technologies that are based on systems used in industry and research.

- Microcontrollers and embedded systems
  - ARM Cortex-based development platforms – Advanced programming and system design.
  - FPGA (Field Programmable Gate Array) technologies – Design of specialized systems optimized for fast data processing.
  - ROS (Robot Operating System) – One of the most important open source development environments in robotics, supporting the development of autonomous systems [33].
- Artificial intelligence and machine learning in robotics
  - Deep Learning applications – Using neural networks for intelligent decision-making and sensing systems in robots (e.g. TensorFlow, PyTorch).
  - Autonomous systems and self-driving vehicles – Algorithms for sensing the environment, route planning and decision-making [34].
  - Image processing and computer vision – OpenCV, YOLO and other object recognition technologies [35].
- Industrial automation and robotic arm control
  - PLC programming – Application of programmable logic controllers, which are common in industrial automation.
  - Collaborative robots (cobots) – Development of robotic systems that work with humans.

Teaching methods in university robotics education

University robotics education places great emphasis on independent research and practical applications, while using modern teaching methods.

1. Blended Learning
   - Students learn the theoretical foundations through pre-recorded videos, online learning materials and research publications.
   - University laboratory classes and seminars focus on the practical application of theory.
2. Flipped Classroom
   - Theoretical knowledge is acquired through online materials, while practical tasks are solved in university labs during classes.
   - With the mentorship of professors and researchers, students can carry out their own robotics projects and research.
3. Project-based learning and research
   - Students develop their own research projects and prototypes.
   - They can participate in international competitions and industrial collaborations, such as RoboCup, DARPA Grand Challenge or AI-controlled drone competitions.

The role of university robotics education in the labor market

Students can prepare for jobs in the fields of industrial automation, artificial intelligence, autonomous systems or even space technology with the skills they acquire during university robotics training. There is an increasing demand for highly qualified professionals in areas such as the development of self-driving vehicles, healthcare robotics or smart manufacturing.

University robotics education is a complex and interdisciplinary field of study that provides students with not only theoretical and practical knowledge, but also opportunities for research and innovation. In

line with the principles of Education 4.0, universities aim to equip students with modern, competitive skills that will enable them to excel in the world of industry and science.

III. EDUCATIONAL METHODOLOGIES IN TEACHING ROBOTICS

The effectiveness of robotics education is significantly increased by the use of modern pedagogical methods that allow students to acquire the necessary skills interactively, through practical problems. The concept of Education 4.0 emphasizes self-study, the use of digital tools and an interdisciplinary approach, which is especially important in the application of robotics and artificial intelligence, especially Deep Learning.

A. Integration of Blended Learning and Deep Learning

The Blended Learning method combines traditional classroom education and online learning, allowing students to master theoretical material at their own pace, while the emphasis in lessons is on practical application and experimentation. This approach is particularly effective in teaching robotics and Deep Learning, where theoretical knowledge can be directly applied through digital tools and simulations.

Deep Learning plays an important role in the Blended Learning model, as students can gain a deeper understanding of how AI works through self-study opportunities and AI-based simulations. Online learning provides students with the opportunity to learn the basics of Deep Learning and Machine Learning on platforms such as Coursera, Udacity, Kaggle or edX, while also gaining hands-on experience through interactive courses. Various simulation tools, such as Google Colab, TensorFlow Playground or PyTorch, provide students with the opportunity to develop and test AI models without the need for high-performance computers. This is especially important in the field of robotics, where AI algorithms can be applied to control autonomous systems, object recognition or human-robot interactions.

Blended Learning in robotics and Deep Learning education is structured according to a four-step model. In the first phase, students are introduced to the basics of AI, machine learning and Deep Learning through online courses and interactive courses. After that, real-time image recognition, sensor data analysis, and robot control tasks are performed in university laboratories and classroom sessions using Python and TensorFlow. In the third stage, students carry out independent project work, where they apply their own AI-based developments, for example, creating a Deep Learning-based object recognition robot. In the final step, students can measure their performance and progress through AI-based code evaluation systems, which provides an opportunity for independent development and optimization of algorithms [36].

B. Flipped Classroom and AI-based Education

The Flipped Classroom method is based on the idea that students learn the theoretical foundations at home, while focusing on practical application and problem solving in class. This model is particularly effective in teaching artificial intelligence (AI) and deep learning, as students can be exposed to algorithms, programming examples, and AI model-building techniques in advance. Theoretical preparation allows them to spend more time in school classes on practical application, optimization, and experimentation with AI [37].

The integration of AI and deep learning into the Flipped Classroom model has several advantages. Online learning opportunities allow students to independently master the principles of AI and deep learning, while testing what they have learned in theory in interactive simulations and virtual environments. Tools like Google Colab, TensorFlow Playground, and PyTorch allow students to experiment and test AI models without the need for major hardware investments.

During classroom sessions, students focus on developing and fine-tuning AI-driven systems. A key element of this is classroom experimentation and optimization, where students can build and test their own robots, autonomous vehicles, or drones controlled by AI models. Teachers act as mentors to help students optimize neural networks, fine-tune algorithms, and troubleshoot potential bugs. This allows students to gain a deeper understanding of how AI works and its real-world applications.

The Flipped Classroom model follows a structured process in the field of robotics and AI development. As a first step, students master the theoretical material and try out AI models at home, for example, working with image and voice recognition systems. During school lessons, AI-driven systems are fine-tuned and tested, for example by developing a self-driving robotic arm or an AI-based object recognition algorithm. In the next stage, students conduct tests in real environments, for example by optimizing the movement of autonomous robots and using sensor data. At the end of the learning process, students can participate in independent projects and competitions, where they can present their own developments, for example by developing Deep Learning-based human-robot interaction systems. The combination of Flipped Classroom and AI-based education not only makes learning more effective, but also promotes problem-oriented thinking and innovation. Students not only acquire theoretical knowledge, but also deepen the practical application of AI and robotics through real-world challenges. This method prepares them to be active shapers of future technological developments [38].

C. Application of Project-Based Learning (PBL) and Deep Learning

Project-Based Learning (PBL) is an educational approach in which students work on solving a given challenge or real-world problem. It is one of the most effective methods in robotics and artificial intelligence (AI) education, as it allows students to apply their interdisciplinary knowledge and develop innovative solutions in real-world environments. During PBL, students not only acquire theoretical knowledge, but also actively experiment, program, and test while working in teams [39].

The integration of Deep Learning further increases the effectiveness of project-based learning by enabling AI models to be trained and applied on real-world data. The following Deep Learning-based projects play a prominent role in robotics education:

- Development of self-driving robots – Deep learning algorithms enable robots to recognize and avoid obstacles, plan routes, and navigate autonomously. Students can use technologies such as Convolutional Neural Networks (CNN) and Reinforcement Learning to optimize the decision-making processes of robots.
- Object Recognition and Image Processing Systems – Students can apply neural networks using OpenCV and TensorFlow to enable robots to automatically recognize objects, people, or different patterns. This technology plays an important role in the development of autonomous vehicles, industrial inspection systems, and medical diagnostic applications.
- Voice-Controlled Robots and Chatbots – Students can integrate AI-based speech recognition models (e.g., Speech-to-Text API, DeepSpeech) into robotic systems, allowing robots to interpret and execute human voice commands. This technology is key to human-robot interaction and the development of intelligent assistants.
- Developing Intelligent Industrial Robots – Students can apply Deep Learning-based optimization to the development of industrial robots, such as automated production lines, quality control systems, and predictive maintenance. With the help of AI, robots will be able to learn from their working environment and dynamically adapt to new situations.

The PBL method not only develops students' technological and programming skills, but also strengthens their independent problem-solving skills, creativity, and teamwork. By combining robotics and Deep Learning, students face real challenges, during which they can gain experience in the practical application of AI and its impact on future technological developments [40].

IV. FUTURE CHALLENGES AND OPPORTUNITIES OF EDUCATION 4.0

Education 4.0 aims to prepare students for the challenges of a digitalized world and to facilitate their active involvement in technological development. Robotics and artificial intelligence (AI), especially Deep Learning, play a key role in this process, as they provide students with the opportunity to interactively master algorithmic thinking, the use of sensors, and the development of autonomous systems. At the same time, the rapid development of technology also poses new challenges for education, which educators and institutions must cope with.

A. Challenges of integrating AI and robotics in education

Although artificial intelligence (AI) and robotics education are becoming increasingly widespread, a number of infrastructural, pedagogical, and ethical barriers hinder their widespread application. The effective implementation of AI-based learning requires not only the availability of technological tools, but also the appropriate training of teachers and students, the development of educational institutions, and awareness of the societal impacts of AI.

Infrastructure and technological challenges

One of the biggest obstacles to AI and robotics education is the lack of technological tools and infrastructure. The acquisition of AI-based robotic systems, microcontrollers, advanced sensors, and computer hardware comes with significant costs that not all schools and universities can afford. In addition, AI and Deep Learning require high computing capacity, which requires advanced servers, cloud computing capabilities, and fast networks. Educational institutions must therefore implement technological developments to provide students with an appropriate environment for using modern AI systems.

Pedagogical and methodological challenges

The integration of robotics and AI into education also poses new challenges in terms of pedagogical methods. Teacher training and in-service training are essential for educators to keep up with technological developments and effectively teach AI. AI-based education can only be successful if teachers are properly trained and can integrate technology into the curriculum in creative and practical ways.

Continuously modernizing the curriculum is also crucial, as AI and robotics are developing at a rapid pace. Educational institutions should not only focus on teaching algorithms and software development, but also incorporate topics such as AI ethics, applications of Deep Learning, and the development of autonomous systems. This will ensure that students not only acquire technical knowledge, but also a comprehensive picture of the social and economic impacts of AI.

Ethical and social challenges

The introduction of AI and robotics into education also raises a number of ethical and social issues that need to be considered as technology advances. AI-based decision-making processes and the operation of autonomous robots raise dilemmas such as data protection, job automation and the question of AI liability. Education must prepare students to understand how AI works and its potential impacts on society, while learning how to use these technologies ethically and responsibly. An additional challenge is the digital divide, as the availability of AI and robotics education varies around the world. Educational institutions in developed countries often have the necessary infrastructure and technological background, while in other regions these opportunities are limited. Education systems must find solutions to make AI-based learning accessible to all students, for example by using open source educational platforms, cloud-based AI simulations and low-cost robotics tools.

B. The potential of AI and robotics for the future of education

Although Education 4.0 faces many challenges, artificial intelligence (AI) and robotics offer significant opportunities for improving education systems. These technologies can make learning processes more efficient, interactive and personalized, while helping to prepare students for the demands of the modern labor market. AI-based tools and robotics developments offer the opportunity to innovatively transform education, which includes adaptive learning, interactive simulations and strengthening industrial relations.

Personalized learning experience

One of the greatest benefits of artificial intelligence is the development of adaptive learning systems that can adapt educational content to the individual needs and abilities of students. AI-based learning provides the opportunity for each student to receive a personalized learning path, taking into account their strengths and areas of development. Such systems, such as intelligent tutors and online platforms, can automatically analyze student performance and provide personalized feedback, facilitating independent learning and development.

Deep Learning-based knowledge assessment can also contribute to personalized education, as AI can accurately identify students' strengths and weaknesses. Automated systems can provide continuous

feedback and help students receive targeted support in areas where they need further practice. This approach can be particularly beneficial in teaching programming, mathematical modeling, and robotics, where practical tasks are key.

Interactive and hands-on learning

AI and robotics offer the opportunity to make education more interactive and experiential. The use of virtual (VR) and augmented reality (AR) in robotics education allows students to test their algorithms and models in realistic simulations. AI-powered virtual labs allow students to test their programs in a safe environment without the need for expensive physical equipment. This solution can be especially useful for educational institutions that do not have adequate robotics infrastructure.

AI-powered collaborative learning systems can also revolutionize education. AI chatbots and digital assistants can help students solve programming problems, provide guidance on troubleshooting, and provide personalized recommendations for further learning materials. This technology not only supports independent learning, but also creates opportunities for collaboration, as students can work together on robotics projects through AI-powered platforms.

Innovation and industry connections

AI and robotics education can bring students closer to real-world industrial and research environments, facilitating university-industry collaborations. Universities and research institutes are increasingly working with industry to enable students to work on real-world problems, such as autonomous systems, industrial automation or healthcare AI systems. AI-based analytical tools enable students to analyze large amounts of real-world data and develop AI-powered systems based on it.

Another important role of education is to encourage AI and robotics entrepreneurship, which gives students the opportunity to found their own startups and develop innovative solutions. In areas such as self-driving vehicles, smart industrial solutions or AI-based medical diagnostics, there is a growing need for young talents who can develop cutting-edge AI algorithms and robotics systems. Universities and research institutes can launch incubation programs that support students in launching and bringing their technology businesses to market.

AI and robotics offer revolutionary opportunities in education, enabling personalized learning experiences, interactive teaching, and strengthening industrial connections. Adaptive learning systems and Deep Learning-based assessments can help ensure that each student receives support that matches their abilities. AI-based simulations, VR/AR technologies, and collaborative learning platforms can make robotics education even more accessible and effective.

The development of technology opens up new opportunities for industrial research and AI-based startups, where students can work on innovative projects and develop their entrepreneurial mindset. The integration of AI and robotics therefore not only revolutionizes learning processes, but also opens new perspectives for future technological developments.

C. Development directions of Education 4.0

The rapid pace of technological development forces education systems to continuously adapt, especially in the field of AI and robotics. One of the most important goals of Education 4.0 is to equip students with digital and technological skills that will enable them to succeed in the future labor market. AI-based learning systems, autonomous robots and intelligent tutors are gaining an increasing role in education, while 5G, IoT and global online platforms are also opening up new opportunities for learning.

AI-based tutors and learning assistants

AI-based tutors and chatbots can revolutionize the learning process by providing personalized support to students. AI systems can analyze student performance in real time, identify problem areas, and offer customized learning materials. Such intelligent learning assistants allow students to progress independently while receiving continuous feedback. AI-based teachers and tutors can be particularly useful in areas such as robotics programming, Deep Learning model development, and data-driven decision-making.

Deep Learning and Human-Robot Interaction Development

Deep Learning and Natural Language Processing (NLP) are increasingly being integrated into educational systems and robotics. In the future, intelligent autonomous systems will be capable of even more sophisticated human-robot interaction, enabling effective communication and collaboration between AI and humans. AI-based robots will become increasingly advanced in terms of emotion recognition, speech recognition, and natural language response, which will create new opportunities in education.

Students will be able to work with humanoid robots and AI assistants that can respond to interactions in real time, promoting the development of creativity, problem-solving, and emotional intelligence. This will be especially important in the fields of medical robotics, customer service AI systems, and intelligent assistants, which will play an increasingly important role in future technology.

Global AI and Robotics Education Platforms

With the rise of distance learning and online learning platforms, students around the world have access to cutting-edge AI and robotics courses. Open-source learning platforms such as Coursera, Udacity, edX, Kaggle, and OpenAI are increasingly offering interactive AI-based courses that enable self-paced learning.

Virtual labs and simulation environments allow students to model and test their algorithms in real-world environments, even if they don't have access to physical robotics labs. AI-based distance learning systems automatically adapt to the pace of students and provide interactive tasks to help them understand more deeply. Such platforms help bridge the digital divide by being accessible from anywhere, at any time, and by providing a wider range of opportunities for AI and robotics education.

The development trends of Education 4.0 show that artificial intelligence and robotics are playing an increasingly important role in educational processes. 5G and IoT technologies will enable students to create real-time AI-driven robotics applications, while AI-powered tutors and learning assistants can facilitate personalized learning [41].

The development of Deep Learning and human-robot interaction has the potential to revolutionize education, especially in the areas of autonomous systems and intelligent assistants. Global AI and robotics education platforms provide opportunities for students worldwide to access the latest technologies and simulations, thus reducing the digital divide.

V. DISCUSSION

The Education 4.0 paradigm places increasing emphasis on the integration of technologies such as robotics and artificial intelligence (AI), especially the application of Deep Learning. These new methods offer students the opportunity to acquire the necessary skills in interactive, real-world problem-based learning environments. At the same time, technological advances also pose a number of challenges that education systems need to address. The following discussion points present the advantages and potential disadvantages of AI and robotics education, as well as future development directions.

One of the most important arguments in favor of supporting AI and robotics education is that these tools provide opportunities for personalized learning and interactive educational experiences. AI-based tutors and adaptive learning systems can create individual learning paths, allowing students to progress at their own pace. The application of Deep Learning allows students to not only acquire theoretical knowledge, but also develop their skills through real-world problems. AI-based knowledge assessment and automatic feedback can help students recognize and correct their mistakes faster, thereby making the learning process more efficient.

Robotics and AI education also promotes the development of creative thinking and innovation, which is essential in the future labor market. In development areas such as autonomous systems, healthcare robotics, and industrial automation, there is an increasing need for specialists who can develop AI-based algorithms and program robotic systems. Countries that timely incorporate these technologies into education can gain a significant competitive advantage in the technology sector.

However, the introduction of robotics and AI education is not without problems and comes with many challenges. One of the most significant obstacles is technological inequality, as the acquisition of

advanced infrastructure and appropriate tools places a significant financial burden on educational institutions. Students living in less developed regions may be disadvantaged if they are not provided with access to AI-based educational systems. Due to funding constraints in schools and universities, adequate robotics labs are not available in many places, while the acquisition of the tools necessary for learning – such as microcontrollers, sensors, advanced computers – also entails significant costs.

VI. CONCLUSION

Education 4.0 is revolutionizing learning processes through the integration of robotics and artificial intelligence (AI), especially Deep Learning. AI-based systems offer personalized learning experiences, while robotic devices facilitate interactive and practical knowledge acquisition. New technologies develop innovative thinking, algorithmic skills, and problem-solving abilities, which are essential in the future labor market.

At the same time, technological inequalities, AI-ethical issues, and the transformation of the role of teachers pose serious challenges. Modern education must find a balance between traditional pedagogy and AI-based learning, ensuring that all students have access to the opportunities offered by technology.

The introduction of Blended Learning and Flipped Classroom methods, as well as open source educational platforms and AI-ethical training, can help make digital education more effective. Future success depends on how education systems can integrate AI and robotics in a way that truly supports learning and makes the benefits of technology accessible to all students.

ACKNOWLEDGMENT

Financial support for this study was provided from the project KEGA 014TTU-4/2024 “Intelligent Animation-Simulation Models, Tools, and Environments for Deep Learning”.

REFERENCES

[1] Udvaros, J. and Forman, N., 2023. Using Artificial Intelligence In Education 4.0. Journal of Technology & Information Education, 15(1).
[2] Végh, L., Takáč, O. and Czakóová, K., 2025. Tracking Students’ Progress in Introductory C Programming Courses through Moodle Tests with Randomized Questions.
[3] Pšenáková, I., Pšenák, P. and Szőköl, I., 2023, September. Flipped Classroom in Pedagogical Practice. In International Conference on Interactive Collaborative Learning (pp. 279-290). Cham: Springer Nature Switzerland.
[4] Czakóová, K., Takáč, O. and Végh, L., 2023. Program Code Simulation by Using Ozobot. International Journal of Advanced Natural Sciences and Engineering Researches, 7(10), pp.441-444.
[5] Czakóová, K. and Csóka, M., 2022. Ozobot coding challenges in elementary school informatics. In INTED2022 Proceedings (pp. 5834-5840). IATED.
[6] Czakóová, K., 2021. Game-based programming in primary school informatics. In INTED2021 Proceedings (pp. 5627-5632). IATED.
[7] Stoffová, V., 2019. Educational computer games in programming teaching and learning. In Conference proceedings of» eLearning and Software for Education «(eLSE) (Vol. 15, No. 01, pp. 39-45). Carol I National Defence University Publishing House.
[8] Dancsa, D., Štempeľová, I., Takáč, O. and Annuš, N., 2023. Digital tools in education. International Journal of Advanced Natural Sciences and Engineering Researches, 7(4), pp.289-294.
[9] Pšenáková, I., Daňo, P., Gloncák, D. and Valo, Ľ., 2024. Applications for Creating Teaching Material for Flipped Classroom Education. Mesterséges intelligencia, 6(1), pp.73-86.
[10] Czakóová, K. and Udvaros, J., 2021. Deep learning in informatics by applying activities of the dash robot. In ICERI2021 Proceedings (pp. 2573-2577). IATED.
[11] Végh, L. and Udvaros, J., 2020. Possibilities Of Creating Interactive 2D Animations For Education Using Html5 Canvas Javascript Libraries. eLearning & Software for Education, 2.
[12] Stoffová, V. and Horváth, R., 2021. Gamification in programming learning. In EDULEARN21 Proceedings (pp. 9253-9258). IATED.
[13] Stoffová, V., 2019. Computer games as a tool for the development of algorithmic thinking. European Proceedings of Social and Behavioural Sciences, 53.

[14] Udvaros, J. and Czakóová, K., 2021. Developing of computational thinking using microcontrollers and simulations. In EDULEARN21 Proceedings (pp. 7945-7951). IATED.
[15] Udvaros, J. and Forman, N., 2023. Artificial intelligence and Education 4.0. In INTED2023 proceedings (pp. 6309-6317). IATED.
[16] Udvaros, J., and Végh, L., 2020. New Teaching Methods By Using Microcontrollers In Teaching Programming, eLearning and Software for Education 2020 : 1 pp. 630-637. Paper: 82 , 8 p.
[17] Udvaros, J. and Takáč, O., 2020. Developing Computational Thinking By Microcontrollers. In ICERI2020 Proceedings (pp. 6877-6882). IATED.
[18] Udvaros, J. and Czakóová, K., 2021. Using teaching methods based on visualizing by TinkerCad in teaching programming. In ICERI2021 Proceedings (pp. 5913-5917). IATED.
[19] Udvaros, J., Forman, N. and Dobák, D.É., 2023. Application and impact of electronic solutions in teaching programming. In Annales Mathematicae et Informaticae (Vol. 57, pp. 78-91).
[20] Udvaros, J., 2019. Teaching Object Oriented Programming By Visual Devices, eLearning and Software for Education 15 pp. 407-413. Paper: 7, 7 p [online]
[21] Végh, L., Czakóová, K. and Takáč, O., 2023. Comparing Machine Learning Classification Models on a Loan Approval Prediction Dataset. International Journal of Advanced Natural Sciences and Engineering Researches, 7(9), pp.98-103.
[22] Végh, L., Annuš, N., Czakóová, K. and Takáč, O., 2024. Improving Machine Learning Classification Models For Anaemia Type Prediction By Oversampling Imbalanced Complete Blood Count Data With Smote-Based Algorithms. Ad Alta: Journal of Interdisciplinary Research, 14(2).
[23] Udvaros, J. and Forman, N., 2024. QR Code Use and Identification Problems in Tourism. Journal of Environmental Management & Tourism, 15(1), pp.167-175.
[24] Pokorný, M., 2021. E-Learning in Manipulative Geometry Teaching. In Conference proceedings of» eLearning and Software for Education «(eLSE) (Vol. 17, No. 01, pp. 247-252). Carol I National Defence University Publishing House.
[25] Pokorný, M., 2024. Interactive Applications Utilization in Teaching Mathematics. R&E-SOURCE, pp.182-192.
[26] Misut, M. and Pokorny, M., 2015. Does ICT improve the efficiency of learning?. Procedia-Social and Behavioral Sciences, 177, pp.306-311.
[27] Pšenaková, I. and Szabó, T., 2018, November. Interactivity in learning materials for the teaching. In 2018 16th International Conference on Emerging eLearning Technologies and Applications (ICETA) (pp. 445-450). IEEE.
[28] Udvaros, J., Gubán, M., Gubán, Á. and Sándor, Á., 2023. Industry 4.0 from the perspective of Education 4.0. International Journal of Advanced Natural Sciences and Engineering Researches, 7(4), pp.230-234.
[29] Coşkun, S., Kayıkcı, Y. and Gençay, E., 2019. Adapting engineering education to industry 4.0 vision. Technologies, 7(1), p.10.
[30] Udvaros, J., Forman, N., Szabó, L. and Szabó, K., 2022. The Importance of Teaching Drones in Logistics. In ICERI2022 Proceedings (pp. 3286-3290). IATED.
[31] Udvaros, J., Forman, N. and Avornicului, M.S., 2023. Developing computational thinking with microcontrollers in Education 4.0. International Journal of Advanced Natural Sciences and Engineering Researches, 7(4), pp.103-108.
[32] Udvaros, J. and Takáč, O., 2022. Technical IT solutions in teaching. In INTED2022 Proceedings (pp. 4047-4052). IATED.
[33] Podlubne, A. and Göhringer, D., 2019. Fpga-ros: Methodology to augment the robot operating system with fpga designs. In 2019 International Conference on ReConFigurable Computing and FPGAs (ReConFig) (pp. 1-5). IEEE.
[34] Radácsi, L., Gubán, M., Szabó, L. and Udvaros, J., 2022. A path planning model for stock inventory using a drone. Mathematics, 10(16), p.2899.
[35] Huang, T.S., Schreiber, W.F. and Tretiak, O.J., 1971. Image processing. Proceedings of the IEEE, 59(11), pp.1586-1609.
[36] Parvat, A., Chavan, J., Kadam, S., Dev, S. and Pathak, V., 2017, January. A survey of deep-learning frameworks. In 2017 International Conference on Inventive Systems and Control (ICISC) (pp. 1-7). IEEE.
[37] Danker, B., 2015. Using flipped classroom approach to explore deep learning in large classrooms. IAFOR Journal of Education, 3(1), pp.171-186.
[38] Chu, S.T., Hwang, G.J. and Tu, Y.F., 2022. Artificial intelligence-based robots in education: A systematic review of selected SSCI publications. Computers and education: Artificial intelligence, 3, p.100091.
[39] Miller, E.C. and Krajcik, J.S., 2019. Promoting deep learning through project-based learning: A design problem. Disciplinary and interdisciplinary science education research, 1(1), p.7.
[40] Jiang, C. and Pang, Y., 2023. Enhancing design thinking in engineering students with project-based learning. Computer Applications in Engineering Education, 31(4), pp.814-830.
[41] Forman, N., Udvaros, J. and Avornicului, M.S., 2023. ChatGPT: A new study tool shaping the future for high school students. Future, 5(6), p.7.