



Introducing Artificial Intelligence and Machine Learning in K12 Education to Foster 21st Century Skills: From Theory to Practice

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Abstract

This paper focuses on the interdisciplinary and collaborative approach underpinning the European funded project Edu4AI “Artificial Intelligence and Machine Learning to Foster 21st Century Skills in Secondary Education”. The methodology has been conceived to enhance the practice of teaching from course design to content delivery, drawing inspiration from social constructivist theories, and inquiry project based learning instructional methods, combining elements from the maker movement and the educational robotics platforms. The final output of this process has been a particle handbook that comprises ready to use project toolkits, suitable to guide the seamless integration of Artificial Intelligence (AI) and Machine Learning (ML) in K12 school curricula, including non-scientific ones. The paper introduces the theoretical frameworks inspiring the toolkits that have been created cooperatively with the teachers’ community and piloted in the school real contexts for validation. One of the toolkit projects is also presented in the article, outlining the corresponding learning goals in terms of both hard and transversal life skills acquired, in order to ensure correspondence with students’ learning outcomes evaluation. Following the presentation of the results from questionnaires collected during the project, the article concludes with some key recommendations for practitioners willing to replicate the initiative.

Keywords: AI; Education; K12; Innovative-Pedagogy; Problem-Based-Skills

1. Introduction

In the realm of education, the integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies holds a significant potential for enhancing students’ learning experiences and preparing them for the demands of the 21st century workforce. Many AI and ML tools are available already, revolutionizing the traditional teaching methods (Chassignol, 2018), including personalizing learning for students, automating instructors’ routine tasks,

and powering adaptive assessments (Seo et al., 2021). Technology integration is no longer to be achieved separately from pedagogical goals, so not only as mediating learning but as tools students learn with, not from, engaging in relevant and meaningful interdisciplinary work to gain understanding of their functionality and real-world applications (Kahn, 2021; Touretzky et al., 2019). However, students often encounter challenges in fully grasping abstract AI concepts, debugging and troubleshooting, understanding the logic, mathematical concepts and application of programming (Yilmaz et al., 2023). The K-12 education on AI concepts, and applications, should underscore the importance of bridging the gap between theoretical knowledge and practical application (Wong et al., 2010) engaging students in critical thinking about the content, and actively participating in knowledge construction (Jonassen, 2020). The goal of learning is to gain new understanding, broaden perspective, and apply knowledge in practice rather than to reproduce a specific set of facts (Wrenn et al., 2009). For younger students, in particular, tangible experiences and multisensory approaches are essential for making AI and ML concepts more accessible and relatable to their everyday lives. Hands-on coding is an effective method as it allows students to apply what they have learned immediately and helps them better understand and retain the material (Handur et al., 2016). As learners engage in the learning process, they construct and negotiate new meanings individually and with others (Shah, 2020) so it is particularly important the students active role understanding and possibly participating in the co-creation of technology and AI tools (Gros, 2016).

Recognizing the need for a more hands-on approach to AI education, the Erasmus+ project Edu4AI “Artificial Intelligence and Machine Learning to foster 21st-century Skills in secondary education” seeks to empower students to explore AI and ML concepts in a playful and interactive manner. With this purpose, it attempts to codify practices that seamlessly integrate AI and ML into the school curriculum, leveraging project-based learning methods inspired by the Maker Movement.

2. Edu4AI theoretical approach to seamlessly integrate AI and ML into the school curriculum

The core methodology of the Edu4AI project encompasses five main phases: the design of a pedagogical framework, the preparation of technical specifications, teachers’ training, and piloting of educational Project Kits in real educational contexts. Through this comprehensive approach, the project endeavors to facilitate the smooth and meaningful incorporation of AI and ML practices into secondary education.

The Edu4AI framework lays a strong emphasis on democratizing AI education, making it accessible to all learners and promoting equity and inclusivity in educational settings. Drawing from Wong's delineation of three key dimensions of AI education - concepts, applications, and ethics/safety - the project conceptualises how contextualized, real-world applications facilitate students' comprehension and engagement. The project endeavours to bridge the gap between theoretical knowledge and practical implementation, leveraging a methodology rooted in the Maker Movement and in the experiential, project-based learning paradigms. This approach emphasizes the importance of experiential learning, where students learn, acquire knowledge, analyse it, and apply it. It highlights the flow of action, reflection, conceptualization, and application (Chan et al., 2018; Blikstein, 2013), immersing students in tangible experiences to deepen engagement and understanding. By introducing AI technologies into schools and piloting step-by-step concrete projects across diverse European locations, the primary objectives have been to empower educators in designing

interdisciplinary AI content and to acquaint students with AI technologies through hands-on endeavours.

Central to the Edu4AI pedagogical framework are considerations of students' prior knowledge, learning styles, and differentiated needs. Through formative assessment strategies, the project has installed a culture of continuous learning and improvement, nurturing students' autonomy and aspirations in mastering AI competencies. By embracing a collaborative and iterative design process - ideate – test – evaluate - improve, educators can leverage the transformative potential of AI to equip students with essential skills for the future workforce (Blinkstein, 2013). Student-centered learning approach, combined with context-oriented curriculum, facilitates experiential learning through hands-on interdisciplinary activities highly connected to real fields of application. This personalized approach aims to cultivate a sense of ownership and relevance among learners, positioning AI as a tangible, and meaningful domain of inquiry, oriented to problem based learning. Hence, once defined the type of curricula, an iterative and collaborative design process (Geramani et al., 2022) can also support the training of other transversal skills such as communication, ability to work in team, leadership. The design of the micro-worlds based on Object-Oriented paradigm (Papert, 1980), makes the learning experience a “growing place” facilitating complex concepts understanding. This approach enhance students motivation to explore and learn and create links between AI and educational priorities for 21st century, and connections between classrooms and the world out there (citizens, families, local communities, local institutions etc.), finally raising awareness about the role of school in the society.

3. Project Kit “Autonomous driving vehicle recognizing traffic signs evaluation”

To operationalize the Edu4AI context-oriented curriculum framework, a suite of instructional materials has been developed, including project presentation templates, teacher guidelines, and student worksheet models, to compose a comprehensive handbook for educators to create meaningful connections between AI concepts and real-world phenomena, fostering interdisciplinary inquiry and problem-solving skills. The handbook includes eight Project Kits including systematic guidance for teachers to implement AI projects with K12 classes, emphasizing clear learning objectives, prerequisites and technical resources, enhanced with relevant Open Educational Resources (OERs) such as teacher's guidelines, students' worksheets and videos¹.

One of the projects included in the handbook is the “Autonomous driving vehicle recognizing traffic signs” project (Figure 1). The project revolves around the idea of creating a DIY vehicle that can autonomously recognize traffic signs through AI techniques, specifically computer vision, image classification, and object recognition. Self-driving cars and robotic vehicles, through AI, can move safely in the environment detecting obstacles, finding the shortest paths and making decisions autonomously. Within this project, students have the opportunity to reflect on the potential benefits and technological, ethical and social challenges associated with the development of autonomous vehicles by exploring the basic concepts of AI. During the project, students are involved in training a model that classifies traffic sign images based on AI image classification services (using Google Teachable Machine), and in creating their own DIY vehicle (based on Raspberry-Py technology) that can autonomously recognize traffic signs and signals and adapt its behavior based on the model

¹ The final and complete version of the materials are available free of charge on Fondazione Mondo Digitale Academy <https://formazione.mondodigitale.org/enrol/index.php?id=103>

previously trained by the students. They can also experiment with object recognition using a pre-trained model with their robotic car.

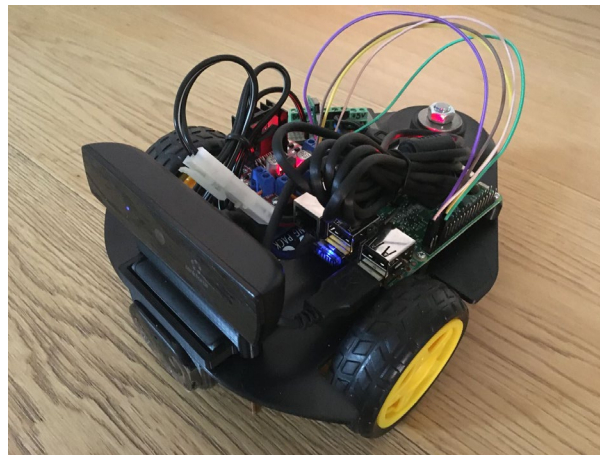


Figure 1: Autonomous driving vehicle recognizing traffic signs

3.1 Learning Objectives

In terms of hard skills students learn what a self-driving car is and become able to identify different levels of autonomy in vehicles. In particular they acquire the capacity to identify examples of systems using AI, different types of AI services and become able to discuss the integration of AI image classification and object recognition techniques. Students acquire knowledge to identify the potential benefits of autonomous vehicles and discuss the related challenges.

Students involved in the project learn to build a DIY robot vehicle based on Raspberry Pi technology and program its movements in python language. They learn to train an AI image classification model with Google Teachable Machine and program the DIY robot vehicle to adapt its behavior integrating the trained model. Moreover, they learn to program the DIY robot vehicle integrating a pre-trained object recognition model.

Learning Objectives			
Knowledge	Through this project students will be able to:	Attitudes	Students will be positive regarding:
	- explain basically what a self-driving car is identifying different levels of autonomy - identify examples of systems using AI and identify different types of AI services - discuss integration of AI image classification and object recognition within a project - identify potential benefits of autonomous vehicles and discuss relevant challenges		
Skills	Students will learn to:		
	- build a DIY robotic vehicle - program the DIY robot vehicle movements - train an AI image classification model - program the DIY robot vehicle to adapt its behavior integrating their AI trained model - program the DIY robot vehicle integrating a pre-trained object recognition model		- the capability of working in groups, sharing competencies and ideas - developing problem solving attitude and strategies - the attitude towards errors: in project-based learning, according to constructionist approach, errors are considered part of the learning process, thus enhancing students' self-confidence - understanding and discussing ethic and social considerations regarding use of AI

Table 1: Learning Objectives.

In terms of soft skills, it is argued that through the project students develop a positive attitude regarding the capability of working in groups, sharing their competencies and ideas. They train their problem-solving skills and gain a positive attitude towards errors (in a constructionist approach, errors are considered part of the learning process, allowing students' self-confidence to increase). Furthermore, they are expected to understand and discuss the ethical and social issues related to the use of AI and, finally, they learn to develop strategies that promote accessibility, inclusion and technological innovation.

3.2 Learning Journey Prerequisites

Some prerequisites were identified as foundational skills or knowledge that can facilitate students engagement with more advanced topics related to the Project Kit Autonomous driving vehicle recognizing traffic signs evaluation, and namely coding skills and knowledge on robotics basics, although the activity can be performed anyway.

Concerning hardware and software prerequisites to implement this project, a Raspberry Pi is necessary, as well as a number of electronic components and materials for the construction of the robotic car, including a webcam. To set up the Raspberry Pi and program the robot vehicle, the Raspberry PI OS with desktop² and the Raspberry Pi Imager software³ are necessary. The Thonny Python IDE is used to develop the program.

To create, train and export the AI image classification model, Google Teachable Machine⁴ is used and a Windows computer or laptop with access to the internet and a webcam are needed. To test the trained model with the robot car, the TensorFlow Lite runtime package for Python is used⁵. With a generic USB webcam OpenCV (Open Source Computer Vision Library) is a good option⁶ to acquire the images. To experiment with object detection github represents an opportunity⁷.

3.3 Piloting the Project Kit: Evaluation Results and Discussion

All the Project Kits were piloted in real educational context and teachers provided valuable feedback through the documentation of their experiences.

The total time estimated for the Project Kit “Autonomous driving vehicle recognizing traffic signs” was estimated to be eight hours, divided into four working sessions, each with an estimated duration of two hours: 1st session for introducing students to concepts related to AI, and particularly to image classification and object recognition, as well as to topics related to autonomous vehicles; a 2nd session for the creation and the programming of the robotic car. After that, 3rd and 4th sessions for training the image classification model, integrating and testing it in the robotic vehicle, as well as for integrating a pre-trained object recognition model, and raising a discussion regarding the differences between the two methods (i.e., image classification and object recognition).

2 <https://www.raspberrypi.com/software/operating-systems>

3 <https://www.raspberrypi.com/software>

4 <https://teachablemachine.withgoogle.com>

5 <https://www.tensorflow.org/>

6 <https://opencv.org>

7 https://github.com/EdjeElectronics/TensorFlow-Lite-Object-Detection-on-Android-and-Raspberry-Pi/blob/master/Raspberry_Pi_Guide.md

The Project Kit “Autonomous driving vehicle recognizing traffic signs“ was piloted and evaluated by 57 students, ages from 15 to 17 years old, in three different countries (i.e., Greece, Italy and Spain). The steps above were intended to be performed in teams of 3 or 4 students. To ease the process, students’ worksheets were provided in each one of these teams, while teachers were moving around, assisting them or giving tips whenever it was necessary.

The project was perceived both by teachers and students as a project of average difficulty. The majority of students who implemented this project did have previous experience on programming but not on python language any did not have previous experience with Raspberry Pi technology. Depending on the students previous experience the actual time needed for completing the project varied from 20 to 40 hours.

By the end of the project, 83,3% of the teachers declared to feel more confident about the possibility to integrate AI into the curriculum in an experiential and creative way (Table 2). The findings highlight the efficacy of hands-on, project-based learning methodologies in fostering teacher readiness and empowerment, and underscore the transformative impact of experiential and creative approaches to AI integration in the curriculum. This heightened confidence among educators not only reflects the success of the project in enhancing pedagogical practices but also signals a broader shift towards innovative teaching paradigms that prioritize active student engagement and real-world application of AI concepts. By equipping teachers with the skills, resources, and confidence needed to navigate the complexities of AI education, these results pave the way for the widespread adoption of experiential learning approaches across educational institutions.

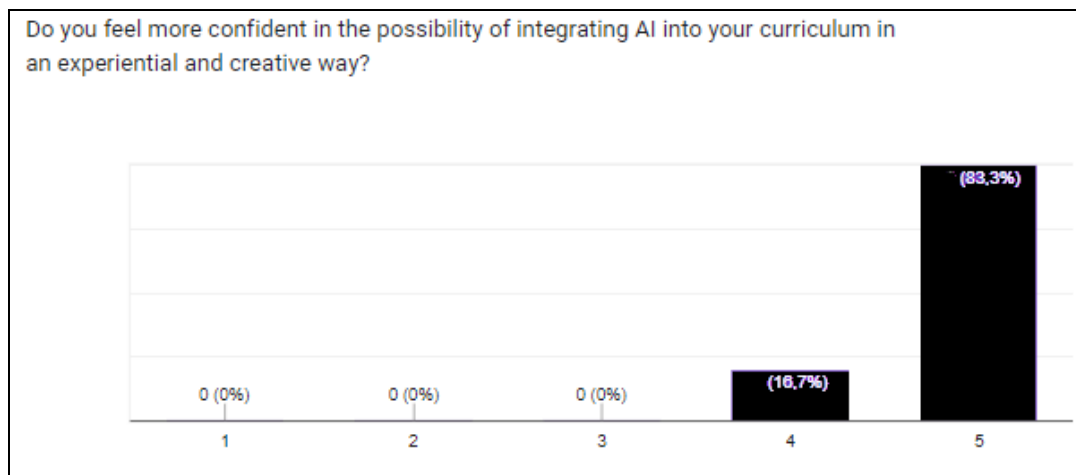


Table 2: Results from teachers’ questionnaires regarding how confidence they gained about the possibility to integrate AI into the curriculum.

By the end of the project, students gained significant knowledge in several key areas. Firstly, they learned about the construction of a robotic artifact, including the assembly of electrical circuits integral to its functioning. Through hands-on experience, students became proficient in the intricate process of assembling and wiring components, fostering a deeper understanding of electronics and engineering principles. Moreover, students acquired essential programming skills, particularly in the Python language, which they applied to control the behavior of the robotic artifact. They learned to write and execute programming commands to facilitate various functionalities, such as movement, navigation, and response to environmental stimuli. Additionally, students explored the integration of artificial intelligence

(AI) methods into their programming, enabling the robotic artifact to exhibit intelligent behavior and adaptability.

One of the project's central objectives was to teach students how to program a robot to recognize and respond to specific stimuli, such as traffic signs, using AI techniques. Through this process, students gained insight into the intersection of robotics, AI, and real-world applications, enhancing their problem-solving abilities and critical thinking skills.

Overall, the project provided students with a comprehensive learning experience, encompassing technical skills in robotics and programming, as well as conceptual knowledge in AI and machine learning. By engaging in hands-on construction and experimentation, students developed practical competencies that are highly relevant in today's rapidly advancing technological landscape.

According to teachers the most valuable aspect of this project was the gained knowledge on working with an AI technology that raised discussions regarding the benefits and the challenges laying behind such practices. Students did enjoy this project, and were thrilled when they managed to set their robotic car in motion. The mean average to the corresponding question was equal to 4,30, turning this into one of the most favorite projects included in the handbook (*Table 3*).

	1	2	3	4	5
How did you like this project - In a scale of 1 (not at all) to 5 (a lot) -	0	2	7	20	28
How easy or difficult was this project for you - In a scale of 1 (very easy) to 5 (very difficult) -	4	15	21	13	4

Table 3: Results from students' questionnaires regarding how much they liked the project and how difficult they think it was.

Some of these statements are also reflected in the feedback received by the students through the questionnaires administered at the end of the experience. Regarding how comfortable/confident they felt to explain different aspects of AI and ML after the implementation of this project, again the majority of answers are positive (*Table 3*). Regarding their feelings towards explaining how AI can be used in real life, 34 students chose 'Yes' as an answer, and 20 'A bit'. Something similar is also reflected in the answers that students gave when they were asked to express how comfortable they were feeling to explain what ML does after the implementation of this project, 31 chose 'Yes', and 23 'A bit' as an answer. The same applies for the question regarding if they were feeling comfortable on experimenting with AI projects, and built and program an AI artifact, since 23 students declared that are feeling 'A bit' confident, 29 of them replied 'Yes' (*Table 4*). Regarding motivation on learning more about AI, 36 students declared that they have been definitely motivated (*Table 5*). Furthermore more, 26 students declared they will definitely reuse the knowledge gained, while 29 will possibly reuse it (*Table 5*).

After this project I feel comfortable to	Yes	A bit	Not at all	Not applicable
Explain what AI is	36	17	4	0
Explain what ML does	31	23	3	0
Explain how AI can be used in real life	34	20	3	0
Experiment with AI projects, building and programming an AI artefact	29	23	4	1

Table 4: Results from students' questionnaires reflecting their attitude towards AI and ML

	Definitely Yes	Maybe	Definitely No	Don't know/Not sure
I feel I can use the gained knowledge and skills in new similar projects	26	29	0	2
This project has motivated me to learn more about AI	36	18	2	1

Table 5: Results from students' questionnaires concerning gained knowledge and motivation

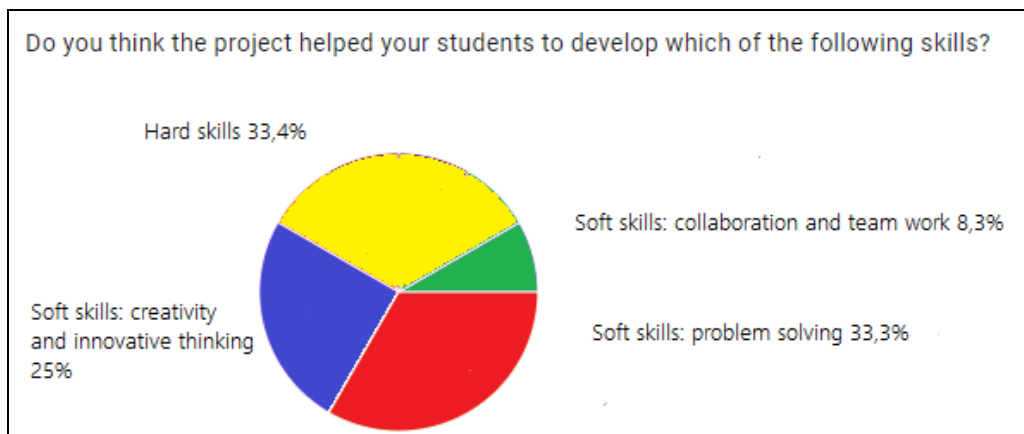


Table 6: Results from teachers' questionnaires concerning gained hard and soft skills

In addition to technical knowledge, students also developed a range of soft skills and attitudes crucial for success in academic and professional settings (Table 6). Throughout the project, students cultivated problem-solving abilities and were actively engaged in collaborative teamwork, acquiring skills and attitudes toward s working collaboratively and communicating effectively, approaching and solving real-world problems while experimenting with alternative solutions regarding programming and speech- to-text technologies. By working together on the construction and programming of the robotic artifact, students learned to leverage each other's strengths, delegate tasks, and resolve conflicts constructively. As they encountered programming obstacles or technical complexities, students applied creative thinking and resourcefulness to devise effective strategies and overcome obstacles. Through this iterative process of trial and error, students learned the importance of perseverance, resilience, and adaptability in the face of adversity. Additionally, students practiced their critical thinking skills by evaluating the efficacy of

different approaches and refining their problem-solving methodologies based on feedback and outcomes.

4. Conclusions and Recommendations for Future Implementations

Based on the above mentioned results, thanks to the direct observation of the activities and the feedback gathered from teachers during the practical activities, this study on integrating Artificial Intelligence (AI) and Machine Learning (ML) into K12 education has provided valuable insights for practitioners willing to replicate the initiative using the materials produced:

Emphasise hands-on, experiential learning: based on the Edu4AI experience, future implementations should continue to prioritize hands-on, and experiential learning approaches. Based on the Edu4AI project experience, providing students with opportunities to engage directly with AI technologies through projects and activities fosters deeper understanding and retention of concepts. In their systematic review of AI education in K-12 classrooms spanning from 2018 to 2023, Lee and Kwon (2024) advocate for a comprehensive approach to AI education. They argue that students should not only understand AI concepts but also be able to apply them to evaluate and create AI solutions. The authors report information about some AI education initiatives incorporating art and media artifacts and technologies (Ali et al., 2021; Alonso, 2020; Henry et al., 2021; Monteith et al., 2022), all concluding that engaging in hands-on exploration with AI technologies enabled students to develop a conceptual understanding of machine learning (ML) principles.

Promote interdisciplinary collaboration: collaboration between educators, researchers, and industry experts is essential for successful AI education. The recognized necessity, as highlighted by NASEM (2018), for all students to have the opportunity to access AI curriculum underscores the importance of educating and providing experiences across disciplines, rather than limiting access to data science education to a narrow subset of students. In addition, the Edu4AI project recommendation is that future implementations should continue facilitating interdisciplinary collaboration to develop comprehensive AI curricula that integrate diverse perspectives and expertise. As the project highlighted, successful initiatives start from supporting teamwork and collaboration.

Empower educators with training and resources: providing educators with the necessary knowledge, skills, and practical ready to use resources enhance their confidence and effectiveness in teaching AI concepts. Evidence from the OECD Teaching and Learning International Survey (TALIS) 2022⁸ indicates that the use of information and communication technology (ICT) for teaching was rarely included in the education and training of lower secondary teachers in EU countries, and poorly trained teachers are consumed by fear and will have low self-confidence about the integration of technology in the classroom (Jamieson-Proctor et al., 2006). By developing, piloting and validating Project Kits in collaboration with teachers, Edu4AI established guidelines to empower, provide resources and build educators confidence to integrate AI into the K12 curriculum.

Foster equity and inclusivity: efforts should be made addressing barriers to access, to ensure equity and inclusivity. Future initiatives are highly recommended to plan for tailored support for diverse learners, as, based on the project results, the initiative is accessible to all learners. The use of AI has had a dual effect, not only on learners with

⁸ TALIS - The OECD Teaching and Learning International Survey 2022

special needs but also on educational institutions by facilitating the development of inclusive teaching methods (Abbasi et al., 2024). The Edu4AI project suggests that activities based on manipulatives, experiments, and arts and crafts, are accessible to all learners and support diverse learners, so fostering equity and inclusivity, addressing the barriers to access and ensured equity and inclusivity.

Evaluate and iterate: continuous evaluation and iteration are essential for improving AI education programs. Future implementations should incorporate feedback from educators and students to identify areas for improvement and make adjustments accordingly. Teachers use assessment feedback to understand students' performance and determine if learning objectives have been met, but the Edu4AI project highlighted an additional perspective regarding how the assessment supports the definition of a curriculum meeting the learners' needs and a learning objectives. Assessment is a crucial component of any course curriculum, influencing both students and course teachers (Subheesh et al., 2020). It motivates students to engage with the subject matter and helps them improve their learning by identifying strengths and weaknesses (Dziob et al., 2018). Feedback provided with assessments allows students to address their learning gaps (Irons, 2007). Similarly, assessments guide course teachers in evaluating their teaching effectiveness and the design of their courses (Black and Harrison, 2001).

Engage stakeholders: stakeholders engagement is critical for the success of AI education initiatives. A stakeholder is defined as “any group or individual who is affected by or can affect the achievement of an organization's objectives” (Freeman and McVea, 2001, p. 2). Future implementations should involve students, parents, policymakers, and industry partners in the design and implementation process to ensure relevance and alignment with policy goals, particularly to ensure the initiative scale up and decision makers support (Miller, 2022).

Promote Ethical and Responsible AI Use: AI education should emphasize the ethical and responsible use of AI technologies. However, their integration raises ethical concerns, necessitates curriculum redesign, requires strategies for continuous learning, and demands alignment with industry standards. While the potential of AI integration in education is promising, there is a notable gap in the existing literature when it comes to exploring the ethical implications, the influence of AI on ESD, the impact on the structure of Blooms Taxonomy, collaboration between academia and industry, strategies for continuous learning, and the effective integration of AI tools for personalized learning (Abulibdeh et al., 2024). Future implementations should expand the discussions on ethical considerations, bias, privacy, and societal impacts into the curriculum to prepare students to navigate ethical dilemmas in AI development and deployment.

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By sharing the outcomes and insights gained from the Edu4AI project, together with Project Kits ready to use, we aspire to inspire and empower educators and schools worldwide to embrace AI education and integrate it into their curricula. Through

collaborative efforts and a commitment to innovation, AI has the potential to positively revolutionize education, empowering students to thrive in an increasingly digital and interconnected world.

References

- Abbasi, M. U. R., Zulfiqar, A., Rasool, M. S., & Quadri, S. S. A. (2024). Impact of AI on the inclusion of Learners with Special needs: Public Policy Perspective in Contemporary Scenario. *Arbor*.
- Abulibdeh, A.O., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal of Cleaner Production*.
- Ali, S., DiPaola, D., Lee, I., Sindato, V., Kim, G., Blumofe, R., & Breazeal, C. (2021). Children as creators, thinkers and citizens in an AI-driven future. *Computers and Education: Artificial Intelligence*, 2, 100040. <https://doi.org/10.1016/j.caeai.2021.100040>
- Alonso, J.M. (2020). Teaching Explainable Artificial Intelligence to High School Students. *International Journal of Computational Intelligent Systems*, 13, 974-987. <https://doi.org/10.2991/ijcis.d.200715.003>
- Black, P., & Harrison, C. (2001). Self-and peer-assessment and taking responsibility: The science student's role in formative assessment. *The School science review*, 83, 43-49.
- Blikstein, P. (2013). Digital fabrication and ‘making’ in education: The democratization of invention. *FabLabs: Of machines, makers and inventors*, 1-21.
- Chan, M. M., & Blikstein, P. (2018). Exploring Problem-Based Learning for Middle School Design and Engineering Education in Digital Fabrication Laboratories. *Interdisciplinary Journal of Problem-Based Learning*, 12(2).
- Chassignol, M., Khoroshavin A., Klimova A., Bilyatdinova A., Artificial Intelligence trends in education: a narrative overview, *Procedia Computer Science*, Volume 136, 2018, Pages 16-24, ISSN 1877-0509, c10.1016/j.procs.2018.08.233.
- Dziob, D., Kwiatkowski, L., & Sokolowska, D. (2018). Class Tournament as an Assessment Method in Physics Courses: A Pilot Study. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(4), 1111-1132. <https://doi.org/10.29333/ejmste/81807>
- Freeman, R. Edward and McVea, John, A Stakeholder Approach to Strategic Management (2001). Available at SSRN: <https://ssrn.com/abstract=263511> or <http://dx.doi.org/10.2139/ssrn.263511>
- Geramani, K.N., Mazzucato, A., Gaudiello, I., & Ioannidis, G.S. (2022). Artificial Intelligence in the secondary education: the paradigm of Edu4AI. *3rd Workshop of Technology Enhanced Learning Environments for Blended Education - The Italian e-Learning Conference, teleXbe 2022*, 3265.
- Gros, B., López, M. (2016). Students as co-creators of technology-rich learning activities in higher education. *Int J Educ Technol High Educ* 13, 28. <https://doi.org/10.1186/s41239-016-0026-x>
- Irons, A. (2007). Enhancing Learning through Formative Assessment and Feedback (1st ed.). Routledge. <https://doi.org/10.4324/9780203934333>
- Jamieson-Proctor, R. M., Burnett, P. C., Finger, G., & Watson, G. (2006). ICT integration and teachers' confidence in using ICT for teaching and learning in Queensland state

- schools. *Australasian Journal of Educational Technology*, 22(4). <https://doi.org/10.14742/ajet.1283>
- Jonassen, D.H. (in press). *Mindtools for engaging critical thinking in the classroom*, 2nd Ed. Columbus, OH: Prentice-Hall.
- Handur V. "Integrating Class and Laboratory with Hands-On Programming: Its Benefits and Challenges," *2016 IEEE 4th International Conference on MOOCs, Innovation and Technology in Education (MITE)*, Madurai, India, 2016, pp. 163-168, doi: 10.1109/MITE.2016.041.
- Henry, J., Hernalesteen, A., & Collard, A. (2021). Teaching Artificial Intelligence to K-12 Through a Role-Playing Game Questioning the Intelligence Concept. *KI - Künstliche Intelligenz*, 35, 171 - 179. <https://doi.org/10.1007/s13218-021-00733-7>
- Kahn, K., & Winters, N. (2021). Constructionism and AI: A history and possible futures. *British Journal of Educational Technology*, 52, 1130–1142. <https://doi.org/10.1111/bjet.13088>
- Lee, S.J., & Kwon, K. (2024). A systematic review of AI education in K-12 classrooms from 2018 to 2023: Topics, strategies, and learning outcomes. *Computers and Education: Artificial Intelligence*. <https://doi.org/10.1016/j.caeai.2024.100211>
- Miller, G.J. (2022). Stakeholder roles in artificial intelligence projects. *Project Leadership and Society*.
- Monteith, B., Noyce, P., & Zhang, P. (2022). Teaching Artificial Intelligence Through the Arts in Beijing. *The Science Teacher*, 89(5), 42-49.
- NASEM (National Academies of Sciences, Engineering, and Medicine) (2018). *Assessing and responding to the growth of computer science undergraduate enrollments*. The National Academies Press.
- Papert, S. (1980). *Mindstorms—Children, Computers and Powerful Ideas*. New York: Basic Books, Inc.
- Seo, K., Tang, J., Roll, I., Fels, S., & Yoon, D. (2021). The impact of artificial intelligence on learner-instructor interaction in online learning. *International journal of educational technology in higher education*, 18(1), 54. <https://doi.org/10.1186/s41239-021-00292-9>
- Shah, R. K. (2020). Concepts of Learner-Centred Teaching. *Shanlax International Journal of Education*, 8(3), 45-60., Available at SSRN: <https://ssrn.com/abstract=4004513>
- Subheesh, N. P., & Sethy, S. S. (2020). Learning through Assessment and Feedback Practices: A Critical Review of Engineering Education Settings. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(3), em1829. <https://doi.org/10.29333/ejmste/114157>
- Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What Should Every Child Know about AI?. *Proceedings of the AAAI Conference on Artificial Intelligence*, 33(01), 9795-9799. <https://doi.org/10.1609/aaai.v33i01.33019795>
- Wong, D., Zink, R. & Koenig, S. (2010). Teaching artificial intelligence and robotics via games. In *Proceeding of the engineering applications of artificial intelligence symposium. (8) (PDF) A review of AI teaching and learning from 2000 to 2020*. Available from: https://www.researchgate.net/publication/365607075_A_review_of_AI_teaching_and_learning_from_2000_to_2020 [accessed Apr 16 2024]

- Wrenn, J., & Wrenn, B. (2009). Enhancing learning by integrating theory and practice. *International Journal of Teaching and learning in higher education*, 21(2), 258-265.
- Yilmaz R., Yilmaz F., The effect of generative artificial intelligence (AI)-based tool use on students' computational thinking skills, programming self-efficacy and motivation, *Computers and Education: Artificial Intelligence*, Volume 4, 2023, 100147, ISSN 2666-920X. <https://doi.org/10.1016/j.caeai.2023.100147>