Artificial Intelligence in the secondary education: the paradigm of Edu4AI

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Abstract

Technology Enhanced Learning (TEL) and Artificial Intelligence can substantially maximise the student learning experience and support students by acquiring both technical and traversal life skills. The COVID-19 pandemic in the last two years has accelerated the introduction of new methods and tools supplementing traditional practices. In this paper we present the methodology posed within the European funded project Edu4AI "Artificial Intelligence and Machine Learning to Foster 21st Century Skills in Secondary Education" to introduce artificial intelligence in secondary education curricula, based on the interdisciplinary cooperation of educational and technical partners from four European countries exploring how user-friendly and mostly graphical environments together with simple engaging pilot projects can be used for this purpose. Furthermore we present the criteria, selection methodology and description of these pilot projects and give an outlook for planned future work.

Keywords

Artificial Intelligence, K-12 curriculum, Machine Learning, AI in Education, Technology Enhanced Learning (TEL)

1. Introduction

The use of information and communication technologies as mediating devices that enhance student learning can include elements of assessment, tutoring, instruction and access to resources that inform learners of new ideas, which they can then reflect upon and integrate into their existing knowledge [1]. Artificial intelligence (AI) systems offer effective support for online learning and teaching, including personalizing learning for students, automating instructors' routine tasks, and powering adaptive assessments [2].

An appropriate use of Information and Communication Technology (ICT) can raise educational quality and connect learning to real-life situations [3]. Technology integration is no longer an isolated goal to be achieved separately from pedagogical goals, but the means by which students engage in relevant and meaningful interdisciplinary work. From this perspective technologies do not directly mediate learning, but are tools students learn *with*, not from.

Learning is mediated by thinking, collaboration, and dialogue facilitated by a variety of tools. Technologies as mind tools support learners as they interpret and organize their knowledge, engage in critical thinking about the content, and actively participate in knowledge construction [4].

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Learners are viewed as active agents who participate actively in the creation of their own knowledge, bringing their experiences and ideas into the learning process, which influences how they learn new information. As learners engage in the learning process, they construct and negotiate new meaning individually and with others [5]. 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 [6]. Thus technology supports the connection of resources, knowledge and students, but students should have active role understanding and possibly participating the co-creation of these tools [7].

As UNESCO highlighted, the connection between AI and education involves three areas: learning with AI (e.g., the use of AI-powered tools in classrooms), learning about AI (its technologies and techniques) and preparing for AI (e.g., enabling all citizens to better understand the potential impact of AI on human lives). The Beijing Consensus on Artificial Intelligence [8] prepared by UNESCO suggests AI as a mean to empower both teachers and learners and to help them gaining both technical and traversal skills and values for their life and work.

Furthermore, Artificial Intelligence is becoming ubiquitous in our society and in our daily life [9] and consequently, a great deal of future career paths for the new generations will undoubtedly be AI-related. For this reason, AI is increasingly included in educational programs as a prerequisite to understand (and operate into) the contemporary world as well as to have access to a significant part of the job market. European networks, national projects, pedagogical research are jointly contributing to define educational standards, didactic patterns and best practices for the introduction of AI at school [10]. However, much has to be done in order to identify effective and rational answers to the "quest for meaning" which is presently carried worldwide in the field of AI education in order to define how AI can "make sense" at school [11].

This paper highlights the benefits that technology enhanced learning with the help of artificial intelligence can bring to students in the secondary education.

The reflections, solutions and products that will be illustrated in the present paper are based on the idea that, in order to build an effective framework for the integration of AI in educational context, it is of the utmost importance to take into account the following challenges:

- Learning design of AI contents for school should implies a special focus on interdisciplinary work through collaborative design thinking practices that go beyond single disciplines;
- In order to spread AI in education and prompt inroads towards AI educational standards, teachers need empowering instructional tools to develop and test structured sequences of unit lessons and projects that can allow the building of AI curricula;
- AI as a subject of study itself needs to be democratized and made accessible for all learners, supporting in this way fairness and equal opportunities in education for all: true innovation does not leave anyone behind [12].

2. The role of AI in Education

The importance of the introduction of AI in education has been highlighted already from the 70s [13]. However serious attempts to introduce AI curricula in schools around the world have started to be made only in the last decade. Khan et al. [14] indicate 2017 as the time when internationally a great deal of activity around AI and education has been recorded. Computer languages specially targeted to children like the MIT App Inventor or Scratch have made that possible. Furthermore the COVID-19 pandemic the last two years has accelerated the introduction of new methods and digital technologies for learning and teaching into schools.

Although generally considered by students as an attractive and to-be-explored subject, AI is often perceived as destined for future Computer Scientists only. Students' representations of AI often include uneasily achievable levels of engineering skills, male-oriented job opportunities, complex and expensive machinery, research-based and abstract learning content [15].

Touretzky et al. [16] as members of the joint working group formed by the Association for the Advancement of Artificial Intelligence (AAAI) developed national guidelines for teaching AI to K-12 students in the USA. This initiative started from the acknowledgment that students in the 21st century need to get familiar with artificial intelligence, machine learning and robotics and concluded with a call to action for the AI community to make easily available demos, resources, or activities that

students and teachers can use and share. Several other similar initiatives around the world indicate both the transformation that has been made and the acknowledgment that students need new methods of learning and acquiring new skills.

Based on the review of best practices conducted within the Edu4AI project it is possible to delineate a broad taxonomy with relation to six main aspects involved in the introduction of AI at school: AI didactic approach; AI teaching/learning formats; AI pedagogical style; AI learning content; AI learning objectives; AI tools.

With relation to the first aspect, three fundamental approaches can be highlighted: didactic of AI (i.e., AI as a field of study, that is, the teaching/learning of technical aspects of AI such as machine learning algorithms, embedded systems, etc.); AI in didactic (i.e. subject-specific lessons which integrates AI as tools to empower and extend knowledge in a discipline, for example a science course illustrating the usefulness and functioning of AI for seabed detection); AI for didactic (i.e. AI based devices and software to support teaching and learning, including personalized adaptive learning, for example automatic translation or e learning platforms aiming at reinforcing specific knowledge).

Concerning the second aspect, several formats are indefinable: structured series of courses covering both hardware and software characteristics of AI [17], [18]: short workshops aimed at providing introductory contents along with hints to further develop knowledge and competences in AI Design Based Research (DBR) interventions [19] to explore new methods and contents [20]; or, project-based lessons with in-deep and purposeful hands-on activities for specific implementation of AI [21].

About pedagogical style, AI activities can vary in terms of amount scaffolding, involvement of teachers in the design of the unit lesson and of AI tools, role of students, high or low ceilingness (i.e. in what extent activities can be developed in an open-ended way [22]).

As for learning content, AI can be subject-related (i.e. connected with a specific school discipline) or subject-independent. Here the choice also depends on the learning context (whether the activities are led in a curricular or extracurricular context), but not uniquely. Lessons about AI often include an introduction about the history of AI (from Turing test to machine learning and deep-learning algorithms) and basic knowledge on machine learning (supervised vs. unsupervised learning [23]). AI is generally presented as a technology capable to sense, process, learn, decide, act. A pedagogical mainstream for K-12 AI education is the so called “Five big ideas” content which focus on:

1. Perception (e.g., speech, sound and object recognition, scene understanding, etc.);
2. Representation and reasoning (i.e., representation of the existing cognitive object such as city maps for the optimization of a path, or representation of a game board to elaborate a successful strategy, or representation of web page content to return specific pages in response to a query);
3. Learning from data (i.e., train an AI device for specific computer vision tasks, or for translation, or to detect the shape and traits of faces etc.);
4. Interaction (i.e., ontologies and domain knowledge required for AI entities to obtain a natural and smart interaction with humans, for examples robotic assistants or conversational agents);
5. Societal impact of AI (i.e., positive or negative effects of AI use, for example: facilitate a care giving community by matching people needs and caregiver availability vs. employ biased data to orient an AI device training to advantage someone and disfavour somebody else, etc.).

Courses on AI also provide an overview of AI applications (autonomous systems, goal-driven systems, patterns and anomalies, recognition, predictive analytics and decisions, conversation and human interaction, hyper-personalisation.

Finally, a relevant part of learning content is often dedicated to responsible or ethical AI (transparency and accountability, data biases, interpretability/explainability, responsible use of data, safety, reasonable use of resources to process data, etc.)

Concerning learning objectives, we can find several categorisations in the literature. A first distinction concerns epistemic components (knowledge, competences and skills related to specific domain, included technical AI domain) and non-epistemic components (soft-skills such as critical thinking, creative problem solving, meta-cognition, collaboration, etc.) of learning objectives. The AI for K12 network [24] distinguishes between Learning Objectives (LO) – what students should be able to do - and Enduring Understanding (EU) – what students should know. For example, when studying how AI processes information, a relevant LO is “analyse one or more online image data-sets and

describe the information the data-sets provide and how this can be used to extract domain knowledge for a computer vision system", while the corresponding EU is: "Domain knowledge in AI systems is often derived from statistics collect from millions of sentences or images"3. In few words, LO describe competencies and skills while EU describe fundamental concepts for a correct understanding of the AI functioning. Another important learning objective is ethics: students should also be aware of limitations and potential of AI in order to be capable of evaluating positive or harmful applications of AI and to project future scenarios [25]. Awareness can be divided in understanding of IA impacts on society (i.e., knowing the effect of non-neutral use of AI technologies), and understanding of the sustainability risks connected to AI functioning (i.e., data-driven learning as source of global warming). Other sources propose, as a comprehensive learning objective, the acquisition of an expertise in AI, which includes AI readiness, AI confidence, AI experience and Life skills (e.g. [26]).

With regards to tools, this can be virtual learning environments where students train AI for specific tasks (e.g., Google's teachable machine, Machine Learning for Kids etc.), or simulation software (e.g., Playground Tensor Flow), but also embedded tools used to combine AI techniques and physical/electronic components to ideate new IoT devices (i.e., AI "infused" into tangible objects). Several tools can be freely accessible on the web, but students and teachers can also engage in the design and testing of original tools, as it is the case for the Edu4AI project.

3. Edu4AI Approach

The Edu4AI project aimed at wisely introducing AI enhanced learning in formal secondary education through a methodology that draws upon the Maker Movement and experiential, project based learning trend in education that immerse the student in action, reflection, conceptualization, and application [27], [28], [29]. By introducing AI technologies into schools and piloting exemplary short projects such as apps and artefact design and construction in different locations in Europe the main goal were to supporting teachers to learning design of AI interdisciplinary contents for school; support students familiarizing with AI in education through making artefacts using these technologies. The methodology proposed inroads towards AI educational standards, empowering teachers with instructional tools to develop and test structured sequences of unit lessons and projects that can allow the building of AI curricula in collaboration with students as active agents; and enhance AI as a subject interdisciplinary democratized subject, accessible for all learners, supporting in this way fairness and equal opportunities in education for all: true innovation does not leave anyone behind.

The framework proposed within the Edu4AI project pedagogical framework, good practices and guidelines takes in consideration the crucial elements shown in Table 1.

Table 1
Elements of the Edu4AI project pedagogical framework

Element	Reasoning
Students' **previous knowledge**, **learning styles** and **differentiation needs**	Take advantage of all the knowledge gained in the last decade on AI pedagogy in order to help teachers in setting **levels of progression for learning objectives** with relation to **different baselines** (prerequisites in Computer science, such as coding skills, etc.); Privilege **accessible tools** to experiment AI (e.g., fee-free software, inter-schools shared resources)
Personal relevance of AI learning experience	Cultivate **a sense of "AI being for me"** by: leveraging learners' interest; Engaging them through a focus on their identity, values and background; Helping them in formulating projections about their future job

	and role in the society
Students-friendly lesson dynamic	Use **gamification techniques** that can facilitate a non-constrained exploration of the AI field, to enable students' familiarization with AI and neutralize possible preconceptions and biases
Future perspective	Encourage **career-relevant lessons**, in which students can discover the significant existing variety of AI professional profiles, including AI women networks1 and ethically relevant jobs such as service-oriented AI
Formative assessment	Develop an **evaluation system** which motivates continuous learning by fostering autonomous training and aspirations towards improvements of AI know-how

A set of instructional materials to scaffold AI didactic were developed within the Edu4AI project to support teachers and trainers developing context-oriented curriculum and related project activities to be piloted with students within the formal educational context: project presentation template, teachers 'guidelines and students' worksheet model. Such templates guides teachers and trainers to:

- Provide a scenario from real life
- Define clear learning objectives (knowledge, skills, attitudes)
- Check prerequisites for students (technical knowledge and skills required)
- Provide Open Educational Resources (OERs) (e.g. videos, how to guides, definitions) to support students in carrying out the projects
- Ensure familiarization of students with tools required (software, hardware)
- Write worksheets for students that will help them follow a sound pedagogical methodology (project-based learning approach)
- Prepare technical solutions for the project (to help teachers themselves feel self-confident)

Context-oriented curriculum helps to build an "AI landscape", that is, to progressively map AI-related learning contents and objectives in a way that fosters subject exploration, case studies analysis, and identification (e.g., students can reflect about how they inhabit such landscape, how they act in it and how they can contribute to develop it in a sustainable way). Furthermore it is useful to create links between AI and educational priorities for 21st century, and to raise awareness about the role of school in the society, by creating connections between classrooms and the world out there (citizens, families, local communities, local institutions etc.). Moreover it helps in creating micro-worlds, for example students-tailored learning scenarios. The first historical definition of micro-world, that we adapt here replacing "mathematics" by "AI" is: a "place", where certain kinds of AI thinking could hatch and grow with particular ease. The design of the micro-world makes it a "growing place" for a specific species of powerful ideas or intellectual structures." (see [30] p. 125). In addition, a context-oriented curriculum facilitates experiential learning through hands-on interdisciplinary activities with relation to real fields of application Hence, once defined the type of curricula, we suggest opting for an iterative and collaborative design process [31], [32]. Iterative design is based on an ideate-test-evaluate-improve cycle which is built through collaboration between teams of teachers.

3.1. Edu4AI Pilot Projects

The result of the curriculum development highlighted several projects to be piloted in schools:

- Semi-autonomous vehicle controlled by the driver's voice commands. Through the Do-It-Yourself (DIY) robotic car a number of crucial parameters, such as the responsiveness of the vehicle to the voice commands, as well as the obstructions that noises or mispronunciations can create, will be investigated, making students aware about the impact (advantages and risks) that the implementation of such technology can have. By the end of the project, students gain significant knowledge about constructing a robotic artefact and create electrical circuits as part of a robotic construction; using programming commands coupled with AI methods to address a specific behaviour to the robotic artefact; programming a robot so that to be

instructed through voice commands,. Furthermore students acquire skills and attitudes towards working collaboratively and communicating effectively, approaching and solving a real-world problems while experimenting with alternative solutions regarding programming and speech-to-text technologies

- Autonomous driving vehicle recognising traffic signs based on Raspberry Pi, Version 4. The Google Teachable Machine has been used for creating, teaching and exporting an AI Image Classification Model. The project suggests navigation of a DIY robotic car implemented on an Arduino IDE and programmed through the MIT App Inventor. Implementing this project, students reflect on self-driving cars simulating a real life scenario and related technological and ethic challenges; exploring AI basic concepts they focus on computer vision aspects and learn about image classification and object recognition. Students train a model that classifies street sign images using AI image classification services. They create their own DIY vehicle capable of recognizing autonomously street signs and signals adapting its behaviour using their trained model. In terms of traversal life skills students enhance their capability of working in groups, sharing competencies and ideas, developing problem solving attitude and self confidence, learning from errors according to constructionist approach. Students also reflects on ethic and social considerations regarding use of AI in daily life.
- Development of a Chatbot, which will have the functions of assistant virtual that will allow automatizing the hard, tedious, and repetitive tasks. This project is a good example to develop students competencies in programming into environments introducing themselves in this studio area. Implementing this project student train their logical as well as creative thinking.
- Students learn about Computer Vision and Artificial Intelligence (AI) by creating and training their own Machine Learning (ML) model with Google Teachable Machine to recognize whether or not a person is wearing a COVID-19 face mask using the Pictoblox software. Implementing the project students train their openness to innovation and mental flexibility.
- Pose recognition, body schema detection in order to create their own app based on dance and on gamification techniques. Students will train a model with Teachable Machine., gaining knowledge about training a model of neural networks; gamification techniques to encourage user engagement; vectorial graphics; notions of rehabilitation. Implementing this project students acquire traversal skills that can be applied in different situations such as communication, creativity, problem solving, empathy, respect for diversity and critical thinking.
- Face recognition project aims to introduce students to Artificial Intelligence and to the most popular programming language in the field of Deep Learning, while refection on emotion analysis and gaining communication skills and emotional awareness.

4. Further directions

The next step brings to the piloting of Edu4AI methodology in the formal teaching and learning context, focusing on the above selected projects that are in progress of being piloted in real classroom context within the activities part of the schools curriculum. During the piloting phase, data will be collected, both qualitatively and quantitatively, to assess the following dimensions: development of technical competencies, development of transversal skills, and impact on teaching and learning practice through the introduction of AI enhanced learning.

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