Didactic activities on Artificial Intelligence: the perspective of STEM teachers

DIDACTIC ACTIVITIES ON ARTIFICIAL INTELLIGENCE: THE PERSPECTIVE OF STEM TEACHERS

Cecilia Fissore[1], Francesco Floris[2], Marina Marchisio[2] and Matteo Sacchet[2]
[1]*Dipartimento di Lingue e Letterature Straniere e Culture Moderne , Via Giuseppe Verdi Fronte 41, 10124 Torino TO, Italy*
[2]*Dipartimento di Biotecnologie Molecolari e Scienze per la Salute , Via Nizza 52 - 10126 Torino TO, Italy*

ABSTRACT

The concept of Artificial Intelligence (AI) might seem something very distant from the world of schools: a theme that is far from today's reality, especially when the education and training system is committed to tackling the problems associated with the pandemic situation. However, the impact that AI is producing in various areas of our life also requires reflection on the world of education and training. Research and education policies are therefore required to direct education to prepare students for technological challenges, enabling schools and teachers to guide innovation. It is necessary to train teachers not only on the theoretical contents inherent to these themes, but also and above all on the planning of didactic activities to adopt innovative educational approaches. The context of this research is the immersive 3-hour workshop on the theme "Mathematics and AI" which involved 52 teachers from all over Italy from primary to secondary school. The research questions are: What is the current teaching practice in schools in Italy in terms of AI? Which characteristics should be emphasized, and which aspects should be favored in the planning of didactic activities by school teachers? To answer the research questions, we analyzed teachers' responses to the initial questionnaire before the workshop and to the final questionnaire at the end of the workshop. Key findings show that teachers do not treat AI-related topics too much with their classes while being aware of the importance of recognizing and understanding AI.

KEYWORDS

Artificial Intelligence, Didactic Activities, Mathematics, Primary School, Secondary School, Teachers

1. INTRODUCTION

When we talk about Artificial Intelligence (AI), we often think of futuristic technologies, robots that behave like human beings making decisions and taking actions and a world in which machines and humans coexist. The world of cinema has also found inspiration for films and TV series on the theme of AI, fueling curiosity but also concerns on the subject. However, AI and its use are much more real than believed and are now used in various aspects of daily life and recently also in the education area at all levels.

In (Digital Education Action Plan 2021-2027), a renewed European Union policy initiative that sets out a common vision of high-quality, inclusive and accessible digital education in Europe, introduces the theme of AI and the importance of updating digital skills curricula to include it. The theme of AI appears in two actions: "Ethical guidelines on the use of AI and data in teaching and learning for educators" (Action 6); and "Updating the European Digital Competence Framework to include AI and data-related skills" (Action 8). The document "The Future of Education and Skills: Education 2030 – OECD" (OECD, 2018) says: "There is a growing demand for schools to prepare students for faster economic and social changes, for jobs that are not created, technologies that have not yet been invented and solving social problems that did not exist in the past". Research and education policies are therefore required to direct education to prepare students for technological challenges, enabling schools and teachers to guide innovation. In the document "Proposals for an Italian Strategy for Artificial Intelligence" (Ministry for Economic Development, 2020) the expert group of the Ministry of Economic Development argues that "The strategy is strongly focused on issues related to education, skills and lifelong learning. One of the fundamental requirements to face this transformation concerns the ability to train figures with digital skills, among which AI plays a leading role. [...] It is necessary to focus not only on improving the skills of the teaching staff already inserted in schools, but also on a structural updating of school curricula".

On the one hand, in fact, students will increasingly need to acquire skills on AI and awareness of the implications of its use. On the other hand, this issue could open new scenarios for teaching practices. To achieve these objectives, it is necessary to understand what is meant by “Artificial Intelligence”, from a theoretical and technical point of view. By doing so, it is possible to understand the opportunities and the limits too, as well as the most immediate and effective areas of application. It is therefore necessary to train teachers not only on the theoretical contents inherent to these themes but also and above all on the planning of didactic activities to adopt innovative educational approaches.

The DELTA Research Group of the University of Turin has developed and implemented two open online courses as an online repository to host curated AI-related training resources. The courses were implemented in collaboration with the Liceo Peano Pellico of Cuneo within their online platform for MOOCs (Liceo Classico e Scientifico Statale "Pellico-Peano" Cuneo - Piattaforma Moodle). The titles of the courses are "Data protection and digital identity awareness" and "STEAM and equal opportunities". The online courses, for teachers and students, contain mathematical didactic activities from primary school to upper secondary school. The courses are part of the Action entitled #FUTURA IA AND DIGITAL CITIZENSHIP, within the National Networks on Innovative Teaching Methods promoted by the Italian Ministry of Education (Basteris et al., 2021). The main objective of the project is to include the issues of AI and digital citizenship within the curricula of the Italian school, being aware that an approach to these issues from a simply technological point of view is not enough, but that it is essential to promote a critical reflection on the social, ethical, and relational aspects that these issues will raise in the future in the short, medium, and long term. As a result of this collaboration involving also the National Ministerial Project Problem Posing and Solving (Fissore et al., 2020), the DELTA Research Group organized a training workshop for teachers on the theme "Mathematics and AI". The context of this research is the immersive 3-hour workshop which involved 52 teachers from all over Italy from primary to secondary school, with a desire to learn and innovate their teaching practices. The workshop took place face-to-face, and it was structured as follows:

- filling in an initial questionnaire;
- theoretical introduction on the topic with group discussion and interactions by teachers;
- illustration of several examples of educational activities of different levels on these topics;
- group planning of a didactic activity through the compilation of a guided form;
- filling in a final questionnaire.

One main reference for the activity of the workshop is the DigCompEdu (Punie et al., 2017), which was mentioned to highlight the educational digital competencies that teachers should consider and develop for effective teaching.

In this paper we analyze the results arising from the answers of teachers about the connection between Ai and education. The research questions are the following:

(RQ1) What is the current teaching practice in schools in Italy in terms of AI?

(RQ2) Which characteristics should be emphasized, and which aspects should be favored in the planning of didactic activities by school teachers?

The paper is structured as follows: in Section 2 the Theoretical background is outlined, in Section 3 research Methodology is presented together with workshop modalities and type of data collected, in Section 4 the Results are illustrated while in the final Section results are discussed and Conclusions are drawn.

2. THEORETICAL BACKGROUND

AI has been introduced as a branch of science that tries to simulate the methods that humans use to solve their problems. The term intelligence is defined as the competence or ability to solve a problem, and artificial means any systematic human method that may accomplish problem-solving goals (Kouveliotis and Mansuri, 2022). AI experts try to teach the machine to act like a human. Thus, intelligence in the expression "Artificial Intelligence" means essentially that implemented models enable a machine to solve problems, in the sense that solutions of these problems have not been a priori encoded, but that they are constructed originally by the machine (Balacheff, 1993). Research in AI has focused chiefly on the following components of intelligence: learning, reasoning, problem solving, perception, and using language (Pedro et al., 2019). AI applications affect the most varied areas of daily life, with important social implications. For this reason, all citizens must be able to understand AI, recognize AI techniques and know the potential and limits of AI. On the one hand, this

implies that the systems must be transparent and explainable even to the user who does not have advanced scientific and technological knowledge; on the other hand, it calls for particular attention to skills, intended both as a necessary tool to develop competitiveness and empowerment and as a tool for protecting the citizen facing the complexities of modern technologies.

In education, AI began producing new teaching and learning solutions that are now undergoing testing in different contexts. However, AI research in the field of education dates back to several years ago. The first significant projects of AI in the field of educational technology for mathematics education appeared in the early seventies (Balacheff, 1993), according to whom the main contribution of AI to mathematics education is to provide concepts, methods, and tools for the design of flexible and relevant computer-based systems for teaching and learning purposes. 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). To prepare teachers for an AI-powered education while preparing AI to understand education is a two-way road: teachers must learn new digital skills to use AI in a pedagogical and meaningful way and AI developers must learn how teachers work and create solutions that are sustainable in real-life environments.

Schools that are expected to adapt to the digital age and embed 21st century skills in their main agendas are some of the main institutions that could be most affected by the development of AI (Gocen & Aydemir, 2020). Karsenti (2019) points out that new forms of technology will fill in our lives and captivate our youth, and this may leave schools with no choice but to make room for them. The online document of UNESCO (Pedro et al., 2019) gathers examples of the introduction of AI in education worldwide, particularly in developing countries, discussions in the context of the 2019 Mobile Learning Week and beyond, as part of the multiple ways to accomplish Sustainable Development Goal 4, which strives for equitable, quality education for all. In particular, the paper explores the different means by which governments and educational institutions are rethinking and reworking educational programs to prepare learners for the increasing presence of AI.

With the increase in studies about AI in the educational field, many scholars in the field want to study how the role of teachers, school and leaders in education will change, and what benefits there may be (see for example Gocen & Aydemir, 2020). In light of the existing initiatives and technologies to come, different studies have recently contributed to the ways in which AI can help improve learning opportunities for students and management systems (Luckin et al., 2016; Pedro et al., 2019). It is certainly important to study what kind of implications it can reveal for the future of schools. However, it is important to introduce the topic in schools, training students and teachers and investigating their perceptions towards AI. Most research in mathematics education aims at the creation of AI milieus to work on mathematics, to the AI-supported learning of mathematics and to the coordination of "usual" paper/pencil techniques and "new" AI-aided educational working spaces (Richard et al., 2022).

Possible topics related to AI and that can be used to introduce the topic and to design educational activities are: Artificial intelligence in everyday life; Machine Learning (the ability to learn without being explicitly programmed); Deep learning (a specific subfield of machine learning); neural networks (from the biological to the computer model); Fuzzy logic (extension of the Boolean logic to manage ambiguity and vagueness, since AI wants to imitate human behavior); Big Data (any collection of data sets so large or complex that it becomes difficult to process them using traditional data management techniques); Data Mining (the process of discovering interesting patterns and knowledge from large amounts of Data); GDPR (General Data Protection Regulation); and personal data protection (education systems must clearly delimit how learners' data are used and be expressly based on learners' consent to their data being used). Also, if AI is to mimic human behavior but algorithms are annotated by humans, they must be bias-free as much as possible. For this reason, AI techniques in educational processes require further study on the issues of the "digital divide" and social inclusion, on the risks associated with these innovations but also on the opportunities that technologies offer to manage these issues with new approaches. Certainly, the topic of AI offers many ideas for the design of interdisciplinary educational activities. The topic of AI is closely related to the concept of 'Learning Analytics' in the literature. Learning analytics is defined as the collection, measurement, analysis, and reporting of information about learners and their context to understand and improve learning and its environments (Long & Siemens, 2011). The spread of AI technologies in education is important for the formation of a flexible, editable curriculum and Learning Analytics can also contribute to the provision of individualized learning content. The function of learning analytics holds a prominent place as an important function of AI applications (Floris et al., 2020; Marchisio et al., 2019).

3. METHODOLOGY

The teachers worked in groups on the guided planning of the didactic activity by filling in a specific form. The form was divided into two parts. The first part "Information on the activity" required title, disciplines involved, class, school, duration, topic, objectives. The second part concerned the description of the activity (type of activity, brief description, supporting digital tools, evaluation).

To answer the research questions, we analyzed the responses of the teachers to the initial questionnaire before the workshop and to the final questionnaire at the end of the workshop. The initial questionnaire was structured in two parts: first part about teachers' data (age, level of education, school, discipline, etc.) and second reflective part. Using Likert scale questions (from 1 = Completely disagree, or Never or Not at all to 5 = Completely agree, or Very often, or A lot) we asked teachers their experience about AI and data protection in the school. In the final questionnaire the teachers reflected on the characteristics of the activity they designed and on how this favors the understanding of different aspects. Furthermore, teachers expressed their appreciation for the workshop in various aspects and for the methodologies of the workshop, for instance adaptive teaching, and formative practices.

Likert scale questions are analyzed through descriptive statistics: median and IQR (Inter Quartile Range).

To answer the research questions, the activities planned by the teachers were also analyzed, some explanatory examples of which will be shown.

The sample of respondents to the questionnaire is composed by 52 teachers for the initial questionnaire. As it can be seen in Figure 1, most respondents are female (69%) in the range 46 – 55 years old (47%) with more than 16 years of teaching experience (58%). Teachers from all grades participated: from primary schools (4%), passing through Lower secondary schools (29%) up to Upper secondary schools (65%). Most participants are teachers in Mathematics (45%), but even other STEM disciplines are represented: Physics (11%), Computer Science (11%), Natural Science (9%). 42 teachers responded to the final questionnaire. Even if some teachers responded only to the initial questionnaire (10 teachers), we consider all their responses as expression of their pre-workshop perspectives on Didactics and AI.

4. RESULTS

The first question of the initial questionnaire (I1) asked the agreement on different sentences about education and AI: the importance of teaching students and teachers to recognize and understand AI, where it intervenes in daily life and the ethics linked to AI, AI education to promote critical thinking and problem solving, the usefulness of understanding AI for students who will not deepen computer science, the awareness about shared data, the importance of managing data and the role of mathematics in conveying issues related to data protection. There is a general strong agreement on these sentences (median 5 over a 5-point Likert scale) with very low dispersion (IQR 0 or 1). Little less agreement on two sentences about the introduction to AI at any school level and mathematics as a vehicle for AI themes (median 4 over a 5-point Likert scale, IQR 1), even though teachers of all grades participated to the workshops.

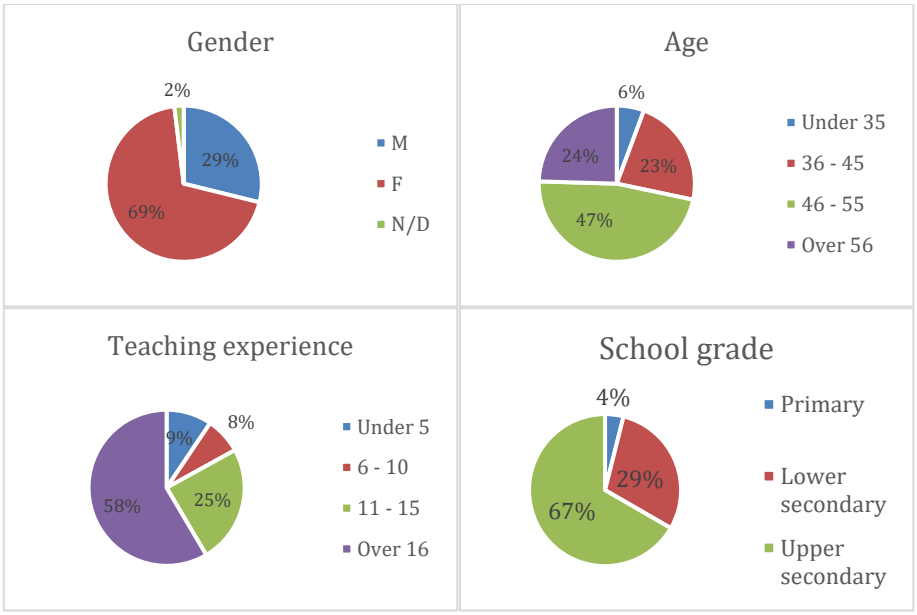

Figure 1. Distribution of Gender, Age, years of Teaching experience, and School grade of respondents

Then, teachers had to respond about how much they treat the topics in Table 1 with the students (I2).

Table 1. Median and IQR related to I2 "How often have you addressed the following topics with your classes?"

Topic	Median	IQR	Topic	Median	IQR
Big Data	2	2	GDPR	2	2
Cryptography	2	2	Digital identity	3	3
Cybersecurity	3	2	AI	2	2
Data ethics	3	1	Machine learning	2	2

It emerges that teachers do not treat AI-related topics a lot with their classes, with cybersecurity being the one that is discussed more than the others. This is probably due to the urgent need of digital literacy for every citizen in Europe and in the world, in order to protect personal and sensitive data, with a focus that is geared more towards practical aspects (how to set up a strong password, how to protect one's own communications, etc.) rather than legal aspects. In fact, the item about GDPR shows rare appearance within classes: anyway, teachers have to deal with the European regulation not in didactics but in other aspects of their job.

The last question of the initial questionnaire (I3) asked teachers their agreement about the use of technologies at school, as it can be seen in Table 2.

Table 2. Median and IQR related to I3 "How much do you agree with the following statements relating to teaching and the use of technologies?"

Topic	Median	IQR
It is recommended to use technologies very often during teaching	4	2
Teachers would need more resources for technology-mediated teaching	4	1
Teachers would need more training for technology-mediated teaching	4	1
Preparing lessons using technologies takes more time	4	2
The use of smartphones within schools must be allowed	4	2
The use of smartphones within schools must be regulated	5	1
The use of smartphones within schools must be prohibited	2	2

The results show that technologies are widely accepted and adopted in daily teaching activities and teachers would like to have more resources and more training to better use technology-enhanced methodologies (median 4 over a 5-point Likert scale). Provocative items investigated the attitude of teachers towards the use of smartphones in education. It is agreed that there must be some regulation to monitor their usage (median 5 over

a 5-point Likert scale), but most teachers even favor it (median 4 over a 5-point Likert scale) and do not agree with prohibitions (median 2 over a 5-point Likert scale).

From the final questionnaire, after one or two hours working on activities related to AI, we asked teachers to mark items on the importance they have given to specific didactical aspects in connection with AI (F1). Results are shown in Table 3.

Table 3. Median and IQR related to F1 "To what extent do you believe that the planned activity favors the following aspects?"

Topic	Median	IQR
Understanding how AI intervenes in daily life	4	2
Understanding the importance of AI	4	2
Understanding the importance of personal data protection	4	2
Understanding the close link between math and AI	4	2

Other questions of the final questionnaire concerned teachers' judgement on the whole workshop. The following aspects are evaluated in (F2): congruence of the training contents with respect to the stated objectives, speakers' mastery of the contents, speakers' communication skills, adequacy of topics to didactical practices, interaction between speakers and participants (median 4 over a 5-point Likert scale). Last question of the final questionnaire (F3) investigates the teachers' point of view on the methodologies to be adopted with students, Table 4. The workshop presented examples of design and implementation of didactical activities on AI-related topics to favor teachers' reflection on the possible applications in the class.

Table 4. Median and IQR related to F3, agreement about the methodologies

Topic	Median	IQR
The proposed methodologies are interesting	5	1
The proposed methodologies are clear	4	1
The proposed methodologies support innovative teaching	5	1
The proposed methodologies support collaborative learning	5	1
The proposed methodologies help students' learning	4	1
The proposed methodologies help students develop skills	5	1
I intend to use the methodologies proposed in the classroom	4	1
I intend to deepen the proposed methodologies	5	1

Beyond a general agreement with the methodologies, teachers aim at emphasizing the following aspects with their activities: Adaptability to different types of students, Peer collaboration, Interactivity, Micro learning, Possibility of alternating different tools and contents in a non-linear way, Use and integration of different techniques and instruments (median 4 over a 5-point Likert scale).

4.1 Examples of Teaching Activities Designed by Teachers

The first example of activity designed by teachers is for a third grade of primary school. The activity is titled "Sensitive Data" and aims to make pupils think about the data that identify people. The disciplines involved are mathematics, history, and civic education. The pupils work as a team on the collection and classification of personal data that identify them. The goal is to create a facsimile of an identity card. The activity can be implemented for the lower secondary school by adding a part on the encryption of personal data and on the sharing of personal data on social networks.

The second example is titled "Applications of Machine Learning to Electron Microscopy". The activity is intended for grade 12 students and the disciplines involved are chemistry and computer science. The goal of the activity is to develop an AI algorithm to recognize from images of microscopic sections of plastics if they are recyclable. The activity consists of 4 parts: classification of plastics on microscopic surfaces; management and cataloguing of images; use of the "Google Colab" environment for the recognition of images of plastic materials; design of the classification algorithm in Python.

The third example is titled "Digital Signals". The activity is intended for grade 11 students and the disciplines involved are electronics, telecommunications, and information technology. The objectives of the activity are to recognize and verify the tolerance band of logic families and to model the real digital signal. The

activity consists of a first part of theoretical introduction on the definition of an ideal and real digital signal, on the 74xx and fuzzy logic families. After an individual asynchronous comparison on the data sheet of the two logic families, a laboratory activity is planned on the assembly of devices of the two logic families. The activity ends with an analysis of the output signals as the input data gradually changes.

The fourth example is titled "AI and biodata to assess the impact of climate change on the ecosystem". The activity is intended for grade 13 students and the disciplines involved are civics, science, mathematics, biology, English. The purpose of the activity is to use new technologies to collect data, structure and analyze them. The objective of the activity is to make students reflect on the phenomenon of climate change through reality assignments.

The activity consists of three parts: photogrammetry for the collection of biodata through the use of the school drone; data structuring using existing python libraries; integration of the dataset with data taken from the network. The digital tools used are Desmos, "Google Colab", drone, digital camera.

5. CONCLUSION

This paper presents the results of a workshop on Mathematics and AI which involved 52 Italian teachers of different levels. The results highlight the current teaching practice in Italian schools about AI-related topics (RQ1). Teachers do not usually treat these kinds of topics in their daily didactics, and the reasons can be multiple: lack of time for topics partly outside their own discipline, (presumed) lack of experience in things related to AI, fear of exploring something beyond their own knowledge. On the other side, teachers perceive the importance of treating AI within classes, since it is a widespread field in computer science and it has numerous applications. When working on activities connecting education and AI, teachers know different characteristics to emphasize (RQ2):

- adaptability, which aims at including from low to high performing students;
- peer collaboration, since AI involves many expertise, group work and collaboration help the development of skills;
- interactivity, in order to let students experiment and put into practice the theoretical aspects;
- micro learning, to distribute and divide learning into atomic elements (learning objects);
- exploring tools and contents in a non-linear way, for example in a learning-by-doing or learning on demand practice;
- use and integration of different techniques and instruments, following multimedia learning principles.

As an overall conclusion from this research, it emerges the greater importance that needs to be given to the issues of artificial intelligence in schools. AI technologies are an exciting area for humankind. Strictly related to this is the need of training teachers on these issues and on the planning of educational activities to propose them to students. AI lends itself very well to interdisciplinary activities (mathematics, computer science, philosophy, history, civics, etc.) and to the design of educational activities for all levels of education. The legal, ethical, pedagogical, psychological, and sociological harms and benefits are to be considered. Subsequently, students' development of digital skills to understand and recognize artificial intelligence, being aware of both the risks and benefits. AI for education includes excitement and promising developments for schools. New developments, contexts and effects can be carefully managed and discussed in classes.

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